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Spacelabs, Inc.

15521 LANARK ST., VAN NUYS, CALIFORNIA

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REPORT NO. SR65-1018

FINAL REPORT

WIRELESS EAR MICROPHONE INTERCOMMUNICATION SYSTEM

NASA CONTRACT
NO. NAS 9-2777

PREPARED FOR:

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

PREPARED BY:

SPACELABS, INC.
15521 LANARK STREET
VAN NUYS, CALIFORNIA

APRIL 16, 1965

FINAL REPORT

WIRELESS EAR MICROPHONE

INTERCOMMUNICATION SYSTEM

NASA/MSC CONTRACT NO. NAS 9-2777

FOREWORD

This report has been prepared in accordance with NASA contract NAS 9-2777, ear microphone wireless intercommunication system. The work under this contract was conducted by Spacelabs, Inc. at Van Nuys, California. This report summarizes the design, fabrication and testing of the "Ear Mike" system.

In compliance with the requirements of the New Technology Clause of the subject contract, a New Technology Report has been submitted to the Technology Utilization Officer, Manned Spacecraft Center, National Aeronautics and Space Administration, Houston, Texas.

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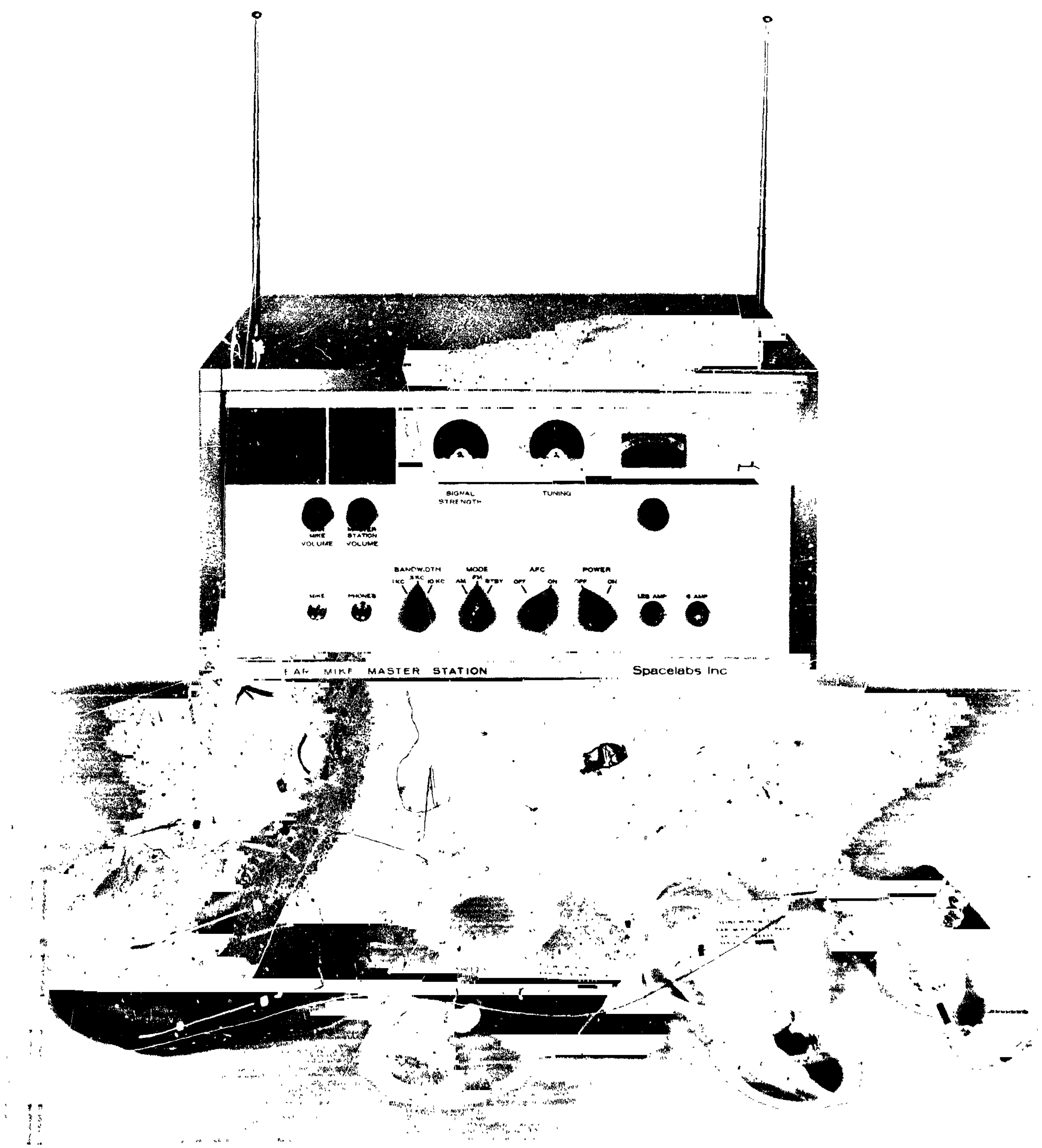
SECTION I

INTRODUCTION

This report describes the work done on the wireless ear microphone communication system ("Ear Mike") under NASA, MSC contract NAS 9-2777. The objectives of this contract were to design, fabricate and test two prototype "Ear Mikes" and a master station.

The "Ear Mike" system, shown in Figure 1, consists of a miniature ear microphone transceiver and a master station. The transceiver senses speech sounds in the ear canal with an acoustic transducer and transmits through an R. F. link to the master station. The master station transmits speech back to the ear mike transceiver which is detected and converted to audio with the same transducer. This technique permits simultaneous two way hands off communication via the ear.

The advantages of this technique are small size, hands off operation and improved performance in high noise environments with the use of ear defenders. The design phase included the selection of an optimum system approach, selection of a suitable transducer, evaluation of ear inserts, development of a diplexing technique, development of the miniature transceiver technique and development of the master station. The fabrication phase included fabrication and test of two prototype units for evaluation by NASA-MSC.


SIGNAL STRENGTH
TUNING
MIKE VOLUME
STATION VOLUME
BANDWIDTH
MODE
AM
FM
STBY
AFC
OFF
ON
POWER
MIKE
PHONES
MASTER STATION
Spacelabs Inc

SECTION II

SUMMARY

A. Technique

The concept of the ear microphone has been previously investigated by several organizations. The original investigations were concerned with direct measurement of the sound pressure level in the ear canal resulting from external sounds. More recent investigators have noted that speech sounds can be sensed in the ear canal. The mechanism of speech pickup in the ear is greatly dependent on bone conduction.

The utilization of an ear microphone also suggests that a dual transducer mounted in the ear can be used for two-way communication through the ear. The drawback to this technique has been the need for a push-to-talk switch or voice-operated switch, common in most communication systems. In 1963 an investigation of ear microphone diplexing techniques (simultaneous talk and listen) was conducted by Spacelabs. The results of this investigation demonstrated speech diplexing with an ear insert microphone. The ear-mounted transducer operated as both a microphone and an earphone simultaneously without a push-to-talk or voice-operated switch.

The work performed by Spacelabs under Contract NAS 9-2777 demonstrated a complete wireless intercommunications system utilizing an ear-mounted transducer, speech diplexer, radio frequency transmitter, and receiver. The device is ear-mounted and permits "hands off" communication over short distances (100 yards).

B. Performance Features of an Ear Microphone

The ear microphone intercommunication system offers several significant features which can increase the performance of existing communication systems and expand the scope of future communications requirements.

1. Speech Diplexing

The speech diplexing technique provides "hands off" communication. This permits communication systems to approach normal face-to-face conversation. This simultaneous two-way feature (similar to the telephone) allows interruption and over-talk.

2. Single Ear-Mounted Package

The entire communication system is mounted on one ear which eliminates the headset and voice or lip microphones currently in common usage. This offers an improvement in several applications where the area near the mouth must be free to perform other functions while communicating, and eliminates breathing noises associated with physical exercise.

3. Small Size

The ear microphone being an ultra-miniature device offers the advantage of small size and light weight. This, coupled with the "hands off" diplexing feature, permits a high degree of mobility.

4. Isolation of External Noise

The ear microphone provides speech pickup in the ear, thus reducing external noise without requiring special noise canceling techniques. Additional noise reduction can be provided by using ear defenders. In extremely high noise environments, noise-canceling techniques can be used further to reduce external noise in the speech pickup.

5. Improved Operation in Severe Environments

The ear microphone will provide improved operation for speech pickup in unusual environments where face masks are required.

6. Time Multiplex RF Link

The radio frequency link operates on a single frequency and provides simultaneous two-way communication by time multiplexing. This offers the potential for adding several two-way links on one frequency without interference between channels. An additional feature of separate party lines can be provided, thus allowing several independent party line conversations in a confined area.

SECTION III

DESIGN - PHASE I

The objectives of the Phase I design effort were to design and develop a breadboard ear microphone system. The tasks included system selection, transducer selection, insert test and selection, transceiver design, diplexer design and master station design. This section describes the effort under Phase I.

A. System Selection

The selection of the communications link technique for the ear microphone wireless intercommunication system is based on the following general requirements:

1. A frequency above 200 mc.
2. Transmission range of 100 yards.
3. Full duplex communication without a voice operated switch.
4. Ear mounted assembly.
5. Growth potential for increasing communication channels.
6. Use of techniques and equipment within the state of the art.

The requirement for full duplex operation without a voice operated switch restricts the system design to two basic techniques, frequency duplex or time multiplex. The requirements for frequency and transmission range do not provide a basis to select between these techniques. The selection of an optimum technique must be based on the complexity, growth potential and state of the art requirements.

1. <u>Frequency Duplex</u>

The frequency duplex technique, shown in Figure 2, provides full duplex operation by transmitting and receiving on two frequencies. The ear mike transmits on f_1 and the master station receiver receives on f_1. The ear mike receives on f_2 and the master station transmitter operates on f_2. The separation between f_1 and f_2 is a function of the receiver bandwidth and shape factor. This difference frequency must be sufficient to provide adequate transmitter to receiver isolation. Considering a simplified model of the RF transmission link the isolation required can be computed:

Sm	Master Receiver Sensitivity	-100 dbm
R =	Transmission Range	100 Yards
f =	Frequency	250 mc
Se =	Ear Mike Receiver Sensitivity	-60 dbm
Gm =	Master Station Antenna Gain	0 db
Ge =	Ear Mike Antenna Gain	-20 db

The master station transmitter power required can be determined from the path loss at 100 yards;

$$\alpha = \frac{Gm\ Ge\lambda^2}{(4\pi)^2\ R^2}$$

$$\alpha_{db} = (0) + (-20) + 2\ (-1)\ -2(11)\ -2(20)$$

$$\alpha_{db} = -84\ db$$

The path loss indicates the master station transmitter power must be

$$P_m = -60\ dbm - (-84\ db)$$

$$= +24\ dbm\ (250\ mw)$$

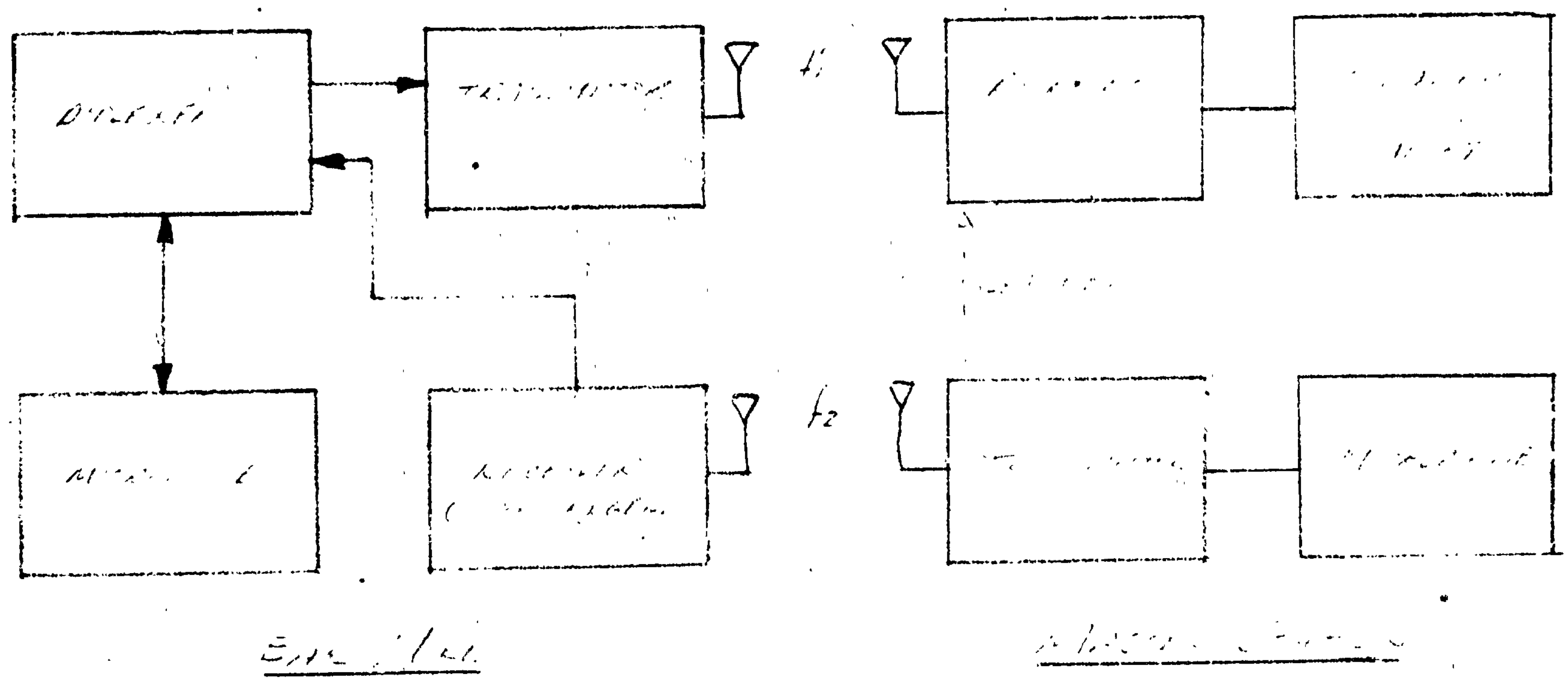


FIGURE 2

The required minimum transmitter to receiver isolation is:

$$\text{Isolation} = P_m - S_m = +24 - (-100)$$
$$= 124 \text{ db}$$

With a receiver shape factor of 4 and a bandwidth of 200 kc the frequency separation must be a minimum of;

Separation = 2.5 mc

Practical considerations limit the isolation that can be achieved. A second factor to be considered in frequency duplex is the ear transceiver antenna requirement. The duplex technique would require two antennas or an antenna switch which limits the goal for microminiaturization. Based on these factors a frequency duplex technique was eliminated as an optimum approach for ear mike communication.

2. <u>Time Multiplex</u>

The time multiplex technique for simultaneous communication with an ear microphone was selected as an optimum approach. The major advantages of this approach are:

1. Ear mike simplicity
2. Utilization of single RF stage
3. Improved master station isolation
4. Single ear mike antenna
5. Adaptibility to microcircuit fabrication

The block diagram of this technique is shown in Figure 3. The ear mike transceiver alternately transmits and receives at a super-audible rate. The master station receives the transmitter pulse train and synchronizes

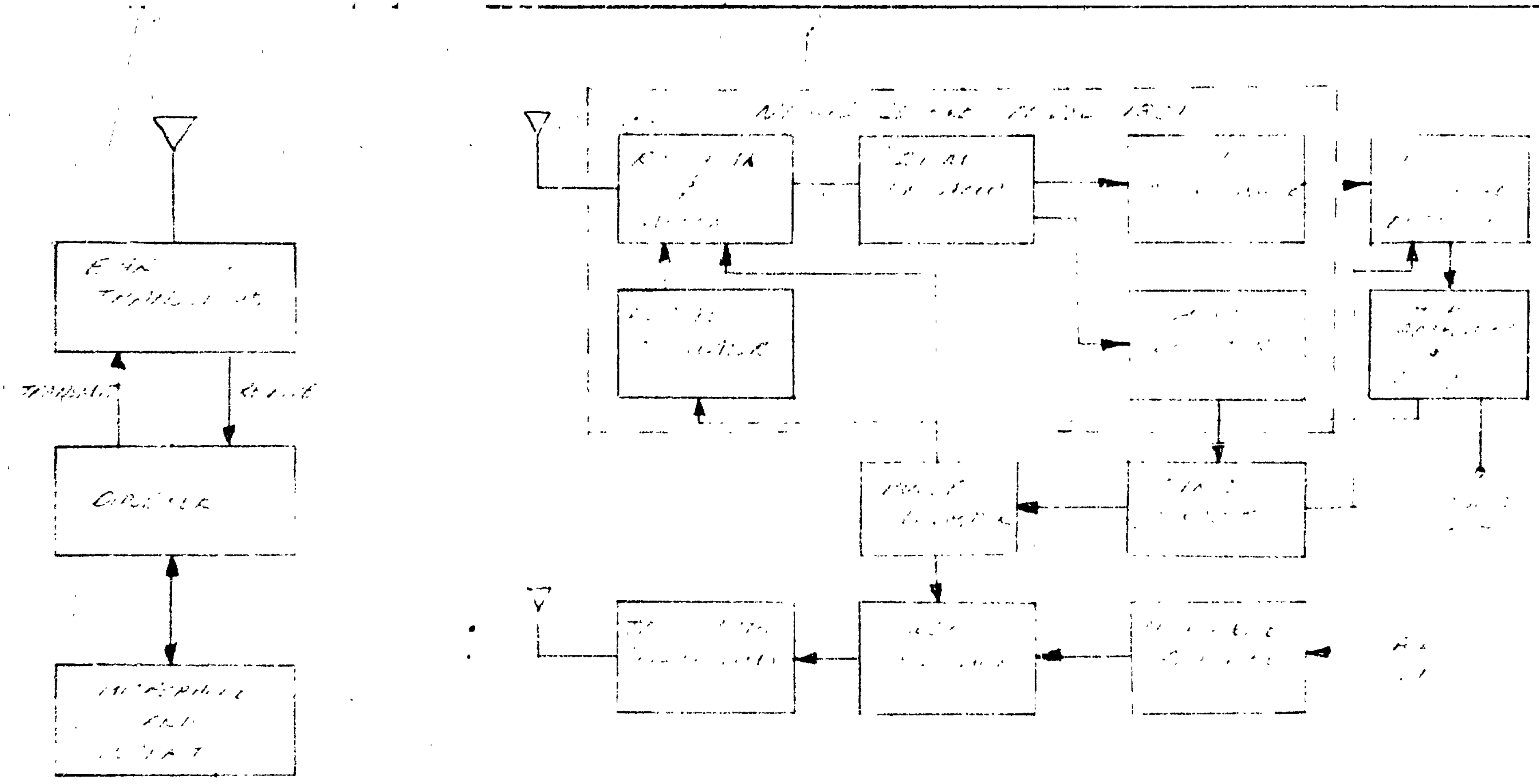


Figure 3

on the leading edge of the ear mike transmitter pulse. The timing relationships for the system are shown in Figure 4. The master station receiver consists of two channels, an AM channel to receive sync pulses and an FM channel to receive the ear mike modulation.

The master station transmitter is delayed from the sync. pulse to assure proper timing. A blanking pulse is also generated to prevent overloading the receiver during transmission. Once synchronization is established, a simultaneous two way link permits both talking and listening.

3. System Performance Parameters

Ear Microphone

Transmitter Type - Pulsed Frequency Modulation

Transmitter Frequency - 220 mc

Transmitter Power (Peak) - 0 dbm (1 milliwatt)

Transmitter P. R. F. - 30 kilocycles

Transmitter Pulse Width - 15 microseconds

Receiver Type - Pulsed Super-regenerative AM Detector

Receiver Frequency - Same as Transmitter

Receiver Bandwidth - 1 megacycle

Receiver Sensitivity - 30 microvolts

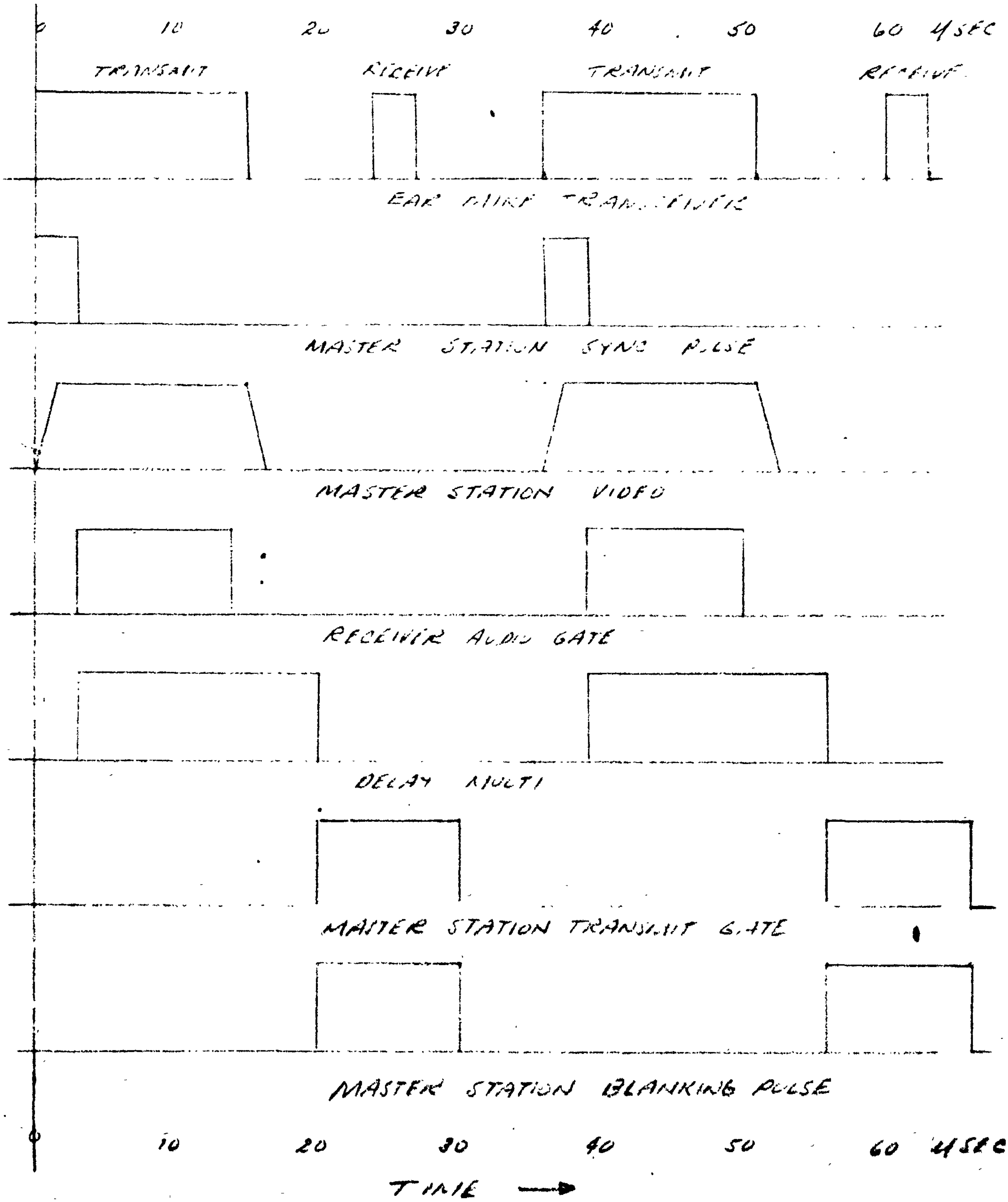
Receiver Pulse Width - 3.0 microseconds

Antenna Gain - -20 db (1% efficient)

Master Station

Transmitter Type - Pulsed Amplitude Modulation

Transmitter Frequency - Same as Ear Microphone



EAR MIKE SYSTEM TIMING RELATIONSHIPS

FIGURE 4

Transmitter Power (Peak) - +30 dbm (1 watt)

Transmitter P. R. F. - Synchronized to Ear Microphone

Transmitter Pulse Width - 10 microseconds

Receiver Type - Super-hetrodyne AM-FM

Receiver Frequency - Same as Ear Microphone

Receiver Bandwidth - 1 megacycle

Receiver Sensitivity - 1 microvolt

Antenna Gain - 0 db

B. Transducer Selection

A survey was conducted to determine the optimum microphone/earphone for use in the ear microphone system. The requirement for an ultraminiature device restricted the types considered to:

(a) Condenser

(b) Crystal/Ceramic

(c) Dynamic/Magnetic

The condenser type requires a high excitation voltage and very high load impedance. The performance characteristics of this type are suitable for the ear microphone. However, to date the smallest unit available (B and K, Model 4135) is too large to fit in the ear and it requires a 200-volt excitation.

The crystal/ceramic type requires a high impedance load. However, it offers excellent performance characteristics for use in an ear microphone. The smallest unit available to date is the Shure CA5A Ultra-Miniature Ceramic Type. The configuration of this unit is not directly suited for an ear microphone. However, with further development of this type, a suitable configuration can be provided.

The dynamic/magnetic types are available in configurations suitable for the ear microphone program. The hearing aid industry uses these types extensively due to their small size and low impedance characteristics. The dynamic types offer better sensitivity and response than the magnetic types. The Knowles BE-1532, BH-1550, and BA-1502 dynamic types were investigated to determine intelligibility both as an ear microphone and earphone. These units were evaluated for suitability for the diplexer. The BA-1502 was selected based on the overall performance and size.

The BA-1502 was tested for response as a microphone and receiver. A typical plot of microphone and receiver response is shown in Figure 5. The receiver response curves show three resonant peaks which are the result of electrical, mechanical and acoustic resonances. The electrical and mechanical properties of the response curve are primarily determined by the device characteristics and significant changes in this response cannot be made with external compensation. The acoustic resonance can be modified by acoustical loading. The techniques for acoustical loading are discussed in the diplexer design.

The selection of the BA-1502 microphone was based on the optimum unit available. However, for optimum performance as an ear microphone transducer, further investigation and development is required. The mechanism for speech pickup in the ear is heavily dependent upon bone conduction. This suggest that a contact transducer can provide optimum signal to noise ratio.

C. Ear Insert Selection

The ear insert selection was based on degradation of intelligibility in a high noise environment, universal fit and comfort. Several types of inserts were investigated including:

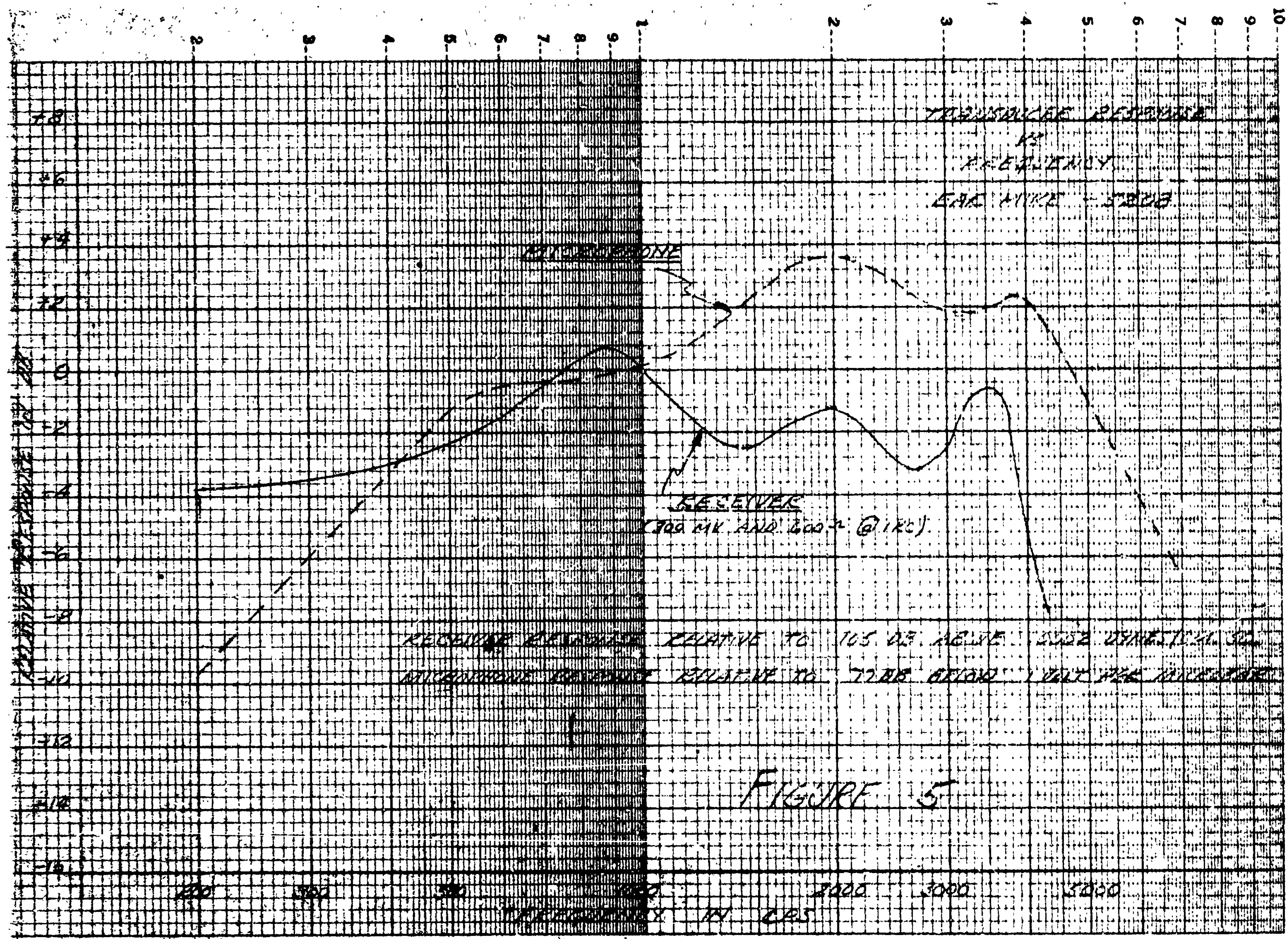

TRANSDUCER RESPONSE
VS
FREQUENCY
MICROPHONE
RECEIVER
(300 MK AND 600 Ω @ 1 KC)
RECEIVER RESPONSE RELATIVE TO 105 DB ABOVE .0002 DYNES/CM SQ
MICROPHONE RESPONSE RELATIVE TO 72 DB BELOW 1 VOLT PER MICROBAR
RELATIVE RESPONSE IN DB
FREQUENCY IN CPS
200
300
500
1000
2000
3000
5000

FIGURE 5

1. Hard plastic custom molded
2. Semi-hard plastic custom molded
3. Soft plyable custom molded
4. Nu-Fit soft universal (6 sizes)
5. Nu-Fit hard universal (6 sizes)
6. Soft universal nipple (3 sizes)
7. Soft silicon universal (1 size)

These inserts (shown in Figure 6) were first evaluated for general characteristics such as comfort, interchangeability, acoustic properties and audio output level. The hard materials provide better sound transmission properties than soft materials. Hard materials are less comfortable than soft materials except for custom molded types. The universal types do not seal as well as custom molded types. The speech spectrum is limited at high frequency in the soft inserts. Best electrical performance was obtained with custom molded inserts but the nu-fit type was very close to the custom molded type.

Specific measurements of sound transmission between the mouth and the ear were not conducted but several general characteristics were qualitatively noted. The main sound transmission mode between mouth and ear is bone conduction. Sounds formed with the lips and tongue are severely attenuated at the ear. The major spectrum of sound at the ear is that characteristic of the larynx and voice box. These factors make the quality of ear sensed speech similar to telephone quality with neither bass or treble present. The spectrum of ear sensed speech is not a simple attenuation function of mouth sensed speech but depends on how and where the sounds are formed. The intelligibility of ear sensed speech approached 100% based on PB word intelligibility tests in a quiet environment.

HARD

SEMI-HARD

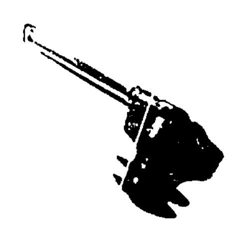
SOFT

CUSTOM MOLDED

SOFT NIPPLE

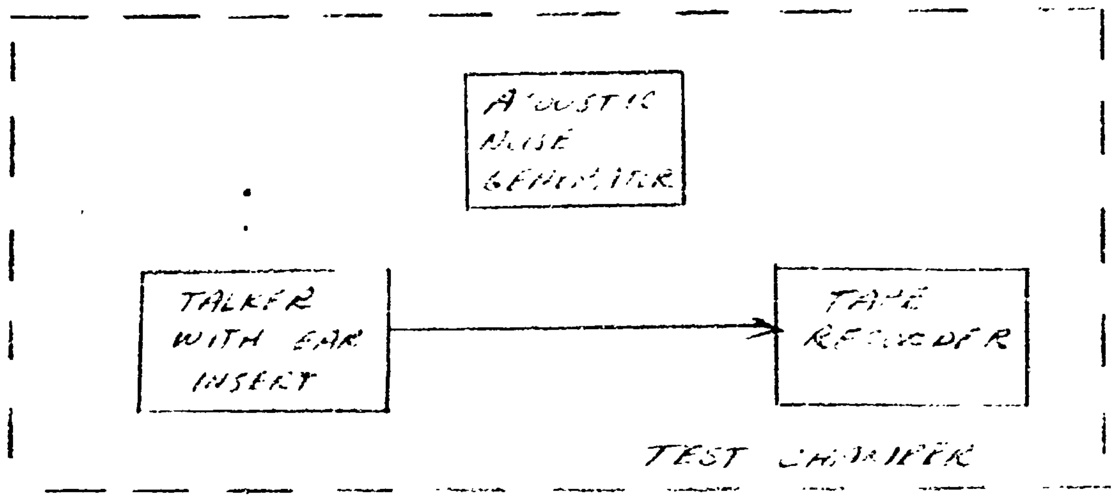
SOFT NU-FIT

HARD NU-FIT



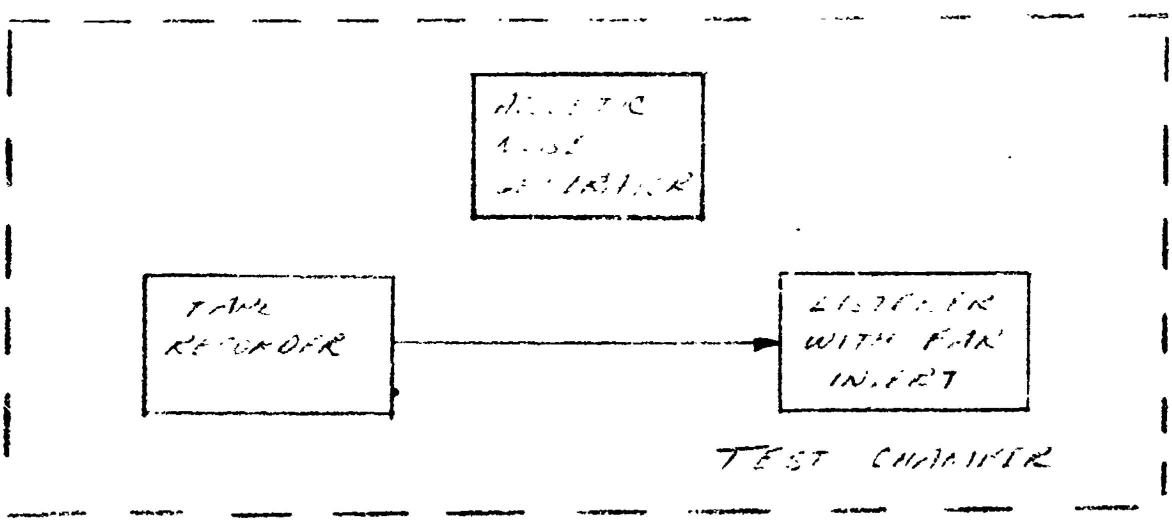
SOFT SILICON

UNIVERSAL



INTELLIGIBILITY TEST RECORDING

QUIET AND 100 DB NOISE



INTELLIGIBILITY TEST PLAYBACK

QUIET AND 100 DB NOISE

FIGURE 7

The inserts selected for evaluation in a high noise environment with both hard and soft custom molded, the nu-fit universal and the universal silicon. All of these inserts are fit to the ear canal up to the boney portion. Attempts to fit the boney portion of the canal result in severe comfort problem for prolonged periods of time.

The intelligibility tests were based on eight subjects. All subjects were fit for custom molded inserts. Each subject was fit for hard and soft types. Audiometer tests were conducted and one subject was disqualified for poor hearing above 5000 cps. All other subjects had normal hearing.

The tests were conducted with phonetically balanced intelligibility word lists of 50 words each. A total of four lists were used for each subject in each environment. Different sets of word lists were used for the different types of inserts. The word lists were recorded by a qualified talker under two conditions in a quiet environment and in a noise environment. The noise level was 100 to 110 db and ear defenders (David Clark, Type 19A) were used during all tests. A diagram of the test setup is shown in Figure 7.

The recorded word lists were played back to the subjects in both quiet and noise environments. A total of 16 different experiments resulted (4 inserts evaluated in 4 environments). Each experiment used 7 subjects. The data obtained is summarized below.

INSERT	ENVIRONMENT Talk-Quiet Listen-Quiet	Talk-Noise Listen-Quiet	Talk-Quiet Listen-Noise	Talk-Noise Listen-Noise
Hard Custom Molded	85%	72%	87%	68%
Soft Custom Molded	37%	73%	85%	78%
Nu-Fit Universal (6 Sizes)	89%	82%	90%	78%
Silicon Universal (1 Size)	85%	76%	86%	74%

The conclusions obtained from this data are:

1. No significant difference exists between listening in noise or listening in quiet.
2. The Nu-Fit Universal insert exhibited the best overall performance.
3. Softer materials are better than hard materials in noise.

The insert selected for the ear microphone was the Silicon Universal based on interchangeability and comfort. A test on four subjects to determine comfort indicated that the insert can be worn for eight hours without major discomfort or irritation to the ear canal.

The final insert configuration shown in Figure 8 included the two microphones, an acoustical loading cavity and the Silicon Universal canal tip. The total insert is fabricated from polyethylene except for the silicon tip.

D. Diplexer Design

The diplexer requires the design to achieve a minimum of 30 db isolation between the receiving and transmitting channels. The BA-1502 microphone was selected


R25
470Ω
MIKE
MIKE

as the ear transducer. The response characteristics of the transducer as both a microphone and receiver are plotted in Figure 5. The technique selected for diplexing was a balanced bridge. The matching of the microphone impedance over the frequency band is required to provide adequate isolation.

An investigation of matching a single microphone in a bridge with passive matchin components provided isolation as high as 20 db over the frequency band. However the resonances in the microphone could not be matched successfully. Several techniques were investigated to linearize the microphone response. Acoustical loading, current feedback in the driver, electrical loading and combinations of these techniques proved inadequate to improve microphone and diplexer characteristics.

The technique yielding the best results was using a second BA-1502 microphone as an impedance matching component as shown in Figure 9. This technique requires selection of matched microphones and can achieve diplexer isolation over the frequency range from 300 to 3000 CPS or 40 db. The microphone selection technique requires that the resonant frequencies in the bandpass be matched. A group of 20 microphones yielded 5 matched pairs with isolation greater than 33 db. The matching setup is shown in Figure 10. The common mode rejection of the oscilloscope must be calibrated to assure accurate results. Typically, the Tektronix 502 provides 40 db CMR (direct in without probes). The CMR can be calibrated to greater than 60 db up to 10 KC. This procedure was followed to match the microphones.

Acoustical loading will effect the match; hence, the final insert design includes a loading cavity for the dummy microphone. The diplexer isolation tests must

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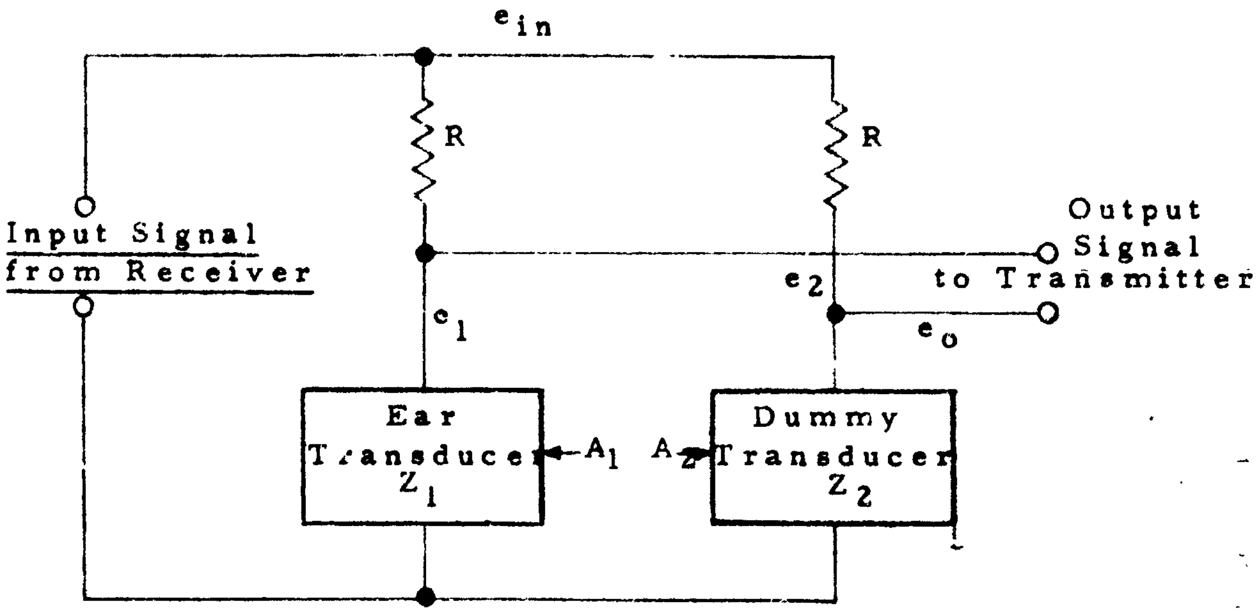


e_{in}	=	Received Signal
e_o	=	Transmit Signal
e_1	=	Signal Across Ear Transducer
e_2	=	Signal Across Dummy Transducer
A	=	Audio Signal to Ear Transducer (Speech Noise)
A_2	=	Audio Signal To Dummy Transducer (Noise)
K_1	=	Audio Gain of Ear Transducer
K_2	=	Audio Gain of Dummy Transducer

$$e_o = e_1 - e_2$$

$$e_1 = e_{in} \frac{Z_1}{R + Z_1} + K1A1$$

$$e_2 = e_{in} \frac{Z_2}{R + Z_2} + K2A2$$

IF $Z_1 = Z_2$, $K1 = K2$ $\quad e_o = A1 - A2 =$ Speech+Noise-Noise

Resistive Bridge Diplexer

Figure 9

MICROPHONE MATCHING SETUP

$$\text{ISOLATION} = 20 \log \left[\frac{2(e_{M_1} - e_{M_2})}{e_{M_1} + e_{M_2}} \right]$$

MINIMUM REQUIRED ISOLATION - 35 DB FROM 200 CPS TO 3500 CPS

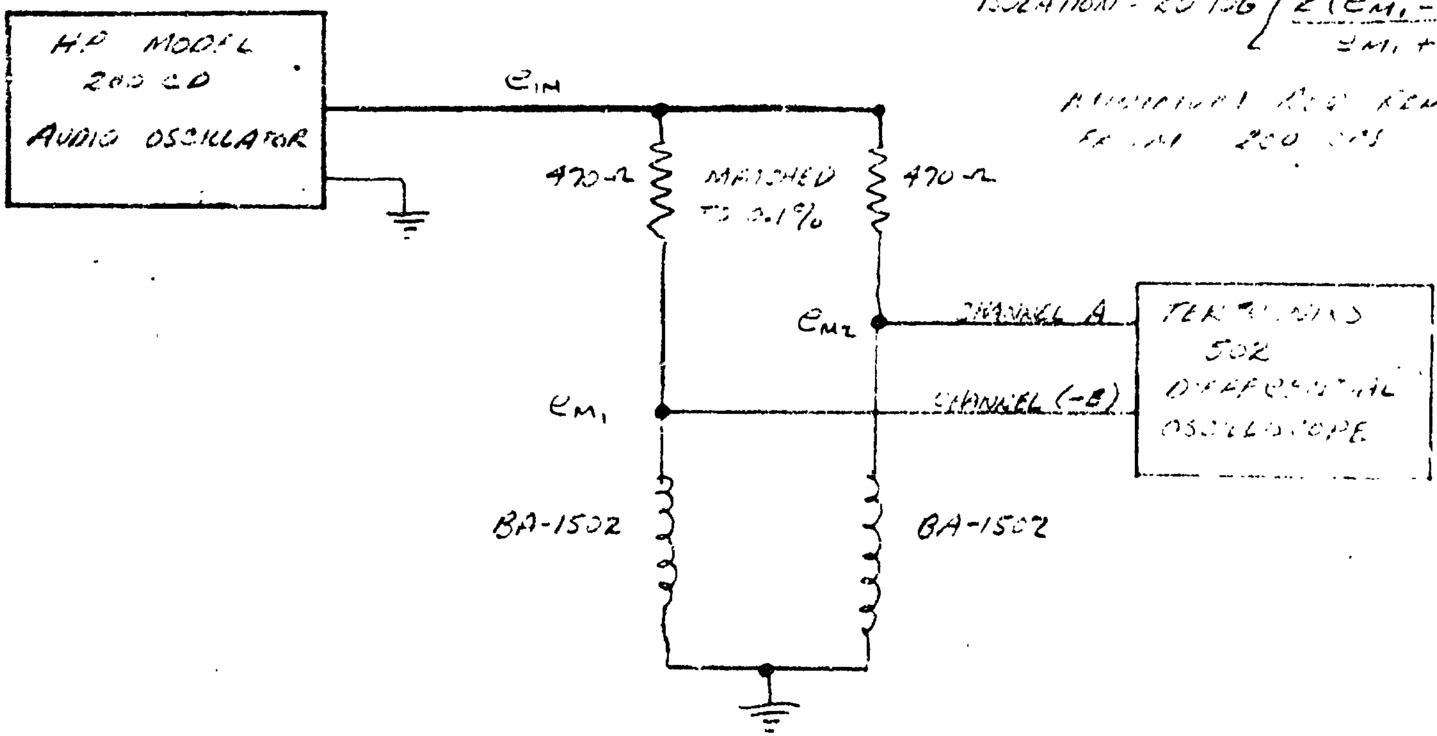


FIGURE 10

be conducted with the active microphone loaded into an acoustical cavity equivalent to the ear canal. A generally accepted load is a 2 cc coupler cavity.

The diplexer also includes an audio amplifier. This amplifier is a high impedance differential amplifier with a single ended output. The common mode rejection is greater than 60 db and the differential gain is 40. A typical output from the BA-1502 microphone is 5 mv (p-p) when mounted in the ear insert at normal speech levels. The diplexer output is 200 mv (p-p) for this signal.

A plot of diplexer isolation vs. frequency is shown in Figure 11. The minimum isolation is 32 db at 2100 CPS. The overall isolation is approximately 40 db. This characteristic is typical of all diplexer tests conducted.

A potential advantage of this diplexer technique is the noise cancelling feature. The dummy matching microphone can be mounted to sense external noise and hence theoretically the difference between the two microphone outputs will be:

Mike #1 Output - Mike #2 Output

Signal + Noise - Noise = Signal

This characteristic depends on two factors. The noise sensed by the dummy microphone is exactly that sensed by the active microphone and that speech is only sensed by the active microphone. The second factor is that the acoustic to electrical signal transfer functions be matched for the pair of microphones. A practical measure of potential improvement can be expected to be 10 db.

E. <u>Transceiver Design</u>

The transceiver is an RF oscillator which is controlled to operate as a time multiplex device. During the transmitter cycle a pulse frequency modulated

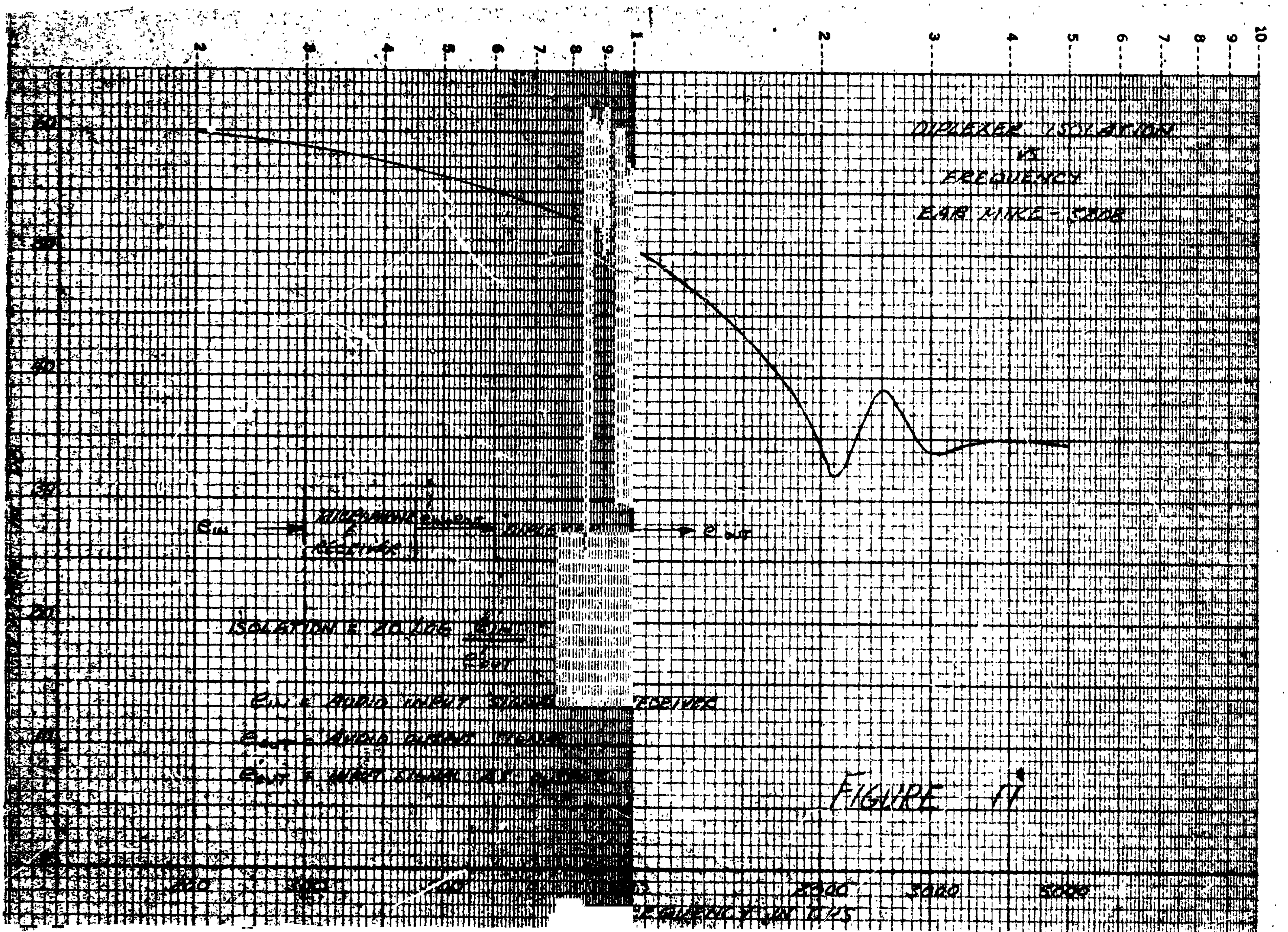


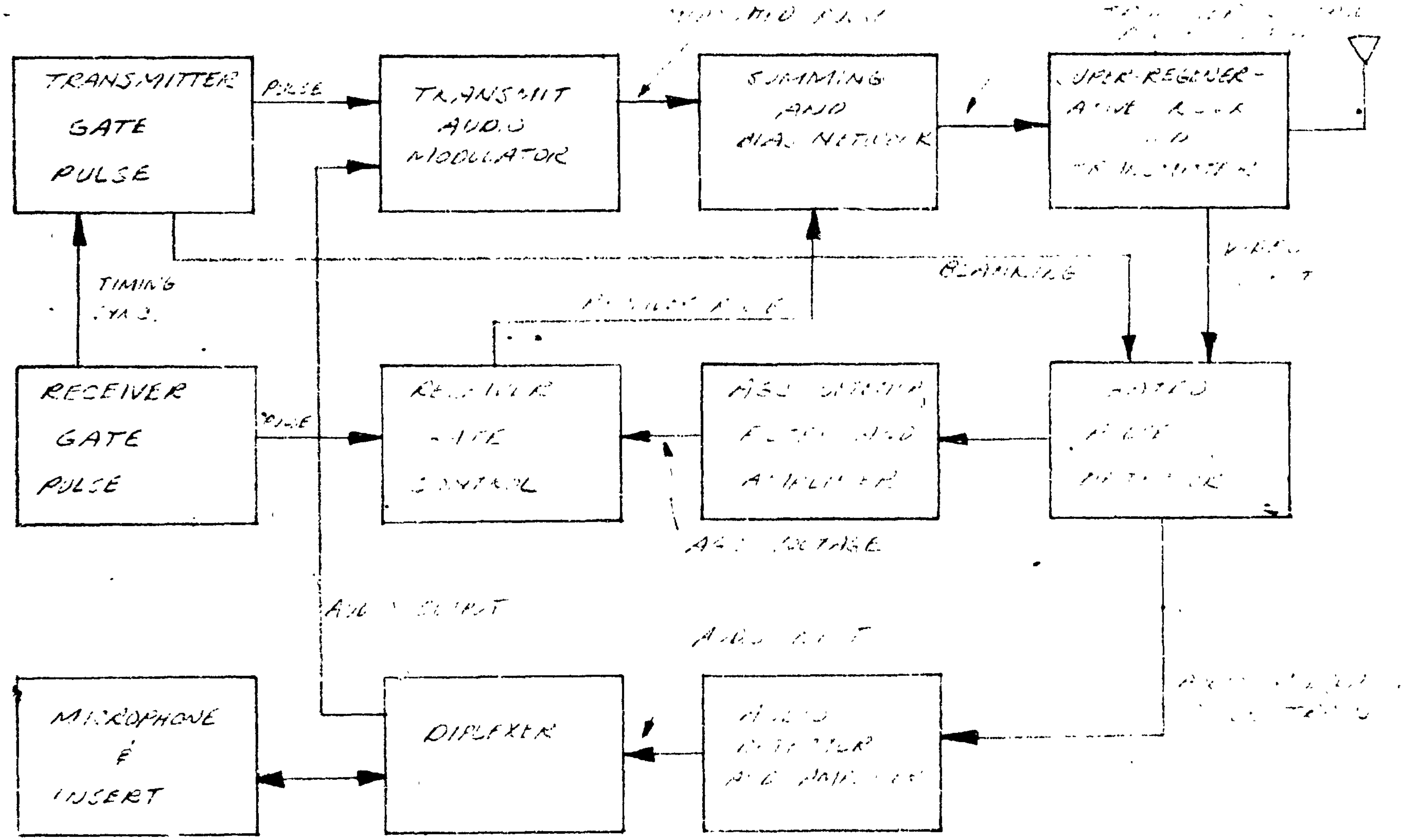
FIGURE 11

signal is generated and during the receive cycle the oscillator operates as a super-regenerative detector. A block diagram of the transceiver is shown in Figure 12. The basic timing relationships between the transmit and receive functions is shown in Figure 13. A schematic is shown in Figure 14.

The operation of the transceiver is initiated by generating the transceiver control waveform. The transmitter gate is synchronized to the receiver gate due to the triggering. The transmitter pulse generator free runs at a frequency slightly slower than one third of the receiver frequency. Every third receiver pulse triggers the transmitter gate, hence, waveform synchronization is obtained. The receiver gate generator operates at approximately 90 KC and the transmitter gate at 30 KC. When these pulses are combined to control the oscillator, only every third receiver pulse is used as shown in Figure 13.

The amplitude of the transmitter gate pulse is modulated with the diplexer output. The receiver pulse amplitude is controlled by the signal derived automatic gain control voltage. These pulses are mixed in the summing and bias network to drive the oscillator.

The RF oscillator is a modified Clapp type as shown in Figure 15. The oscillator is normally biased off to quench oscillation. Operation is initiated with the transmitter pulse which provides base bias to the transistive Q_1. The feedback network L_2, C_1, Cfb and Cin determine the frequency of the oscillator. The antenna is tapped off the collector coil to provide an impedance match. The oscillator builds up rapidly when the transmitter pulse is applied. FM modulation is provided due to the capacitance variations in Cfb and Cin with pulse amplitude. A plot of these variations and the frequency sensitivity is shown in Figure 16.



Ear Microphone Block Diagram

Figure 12.

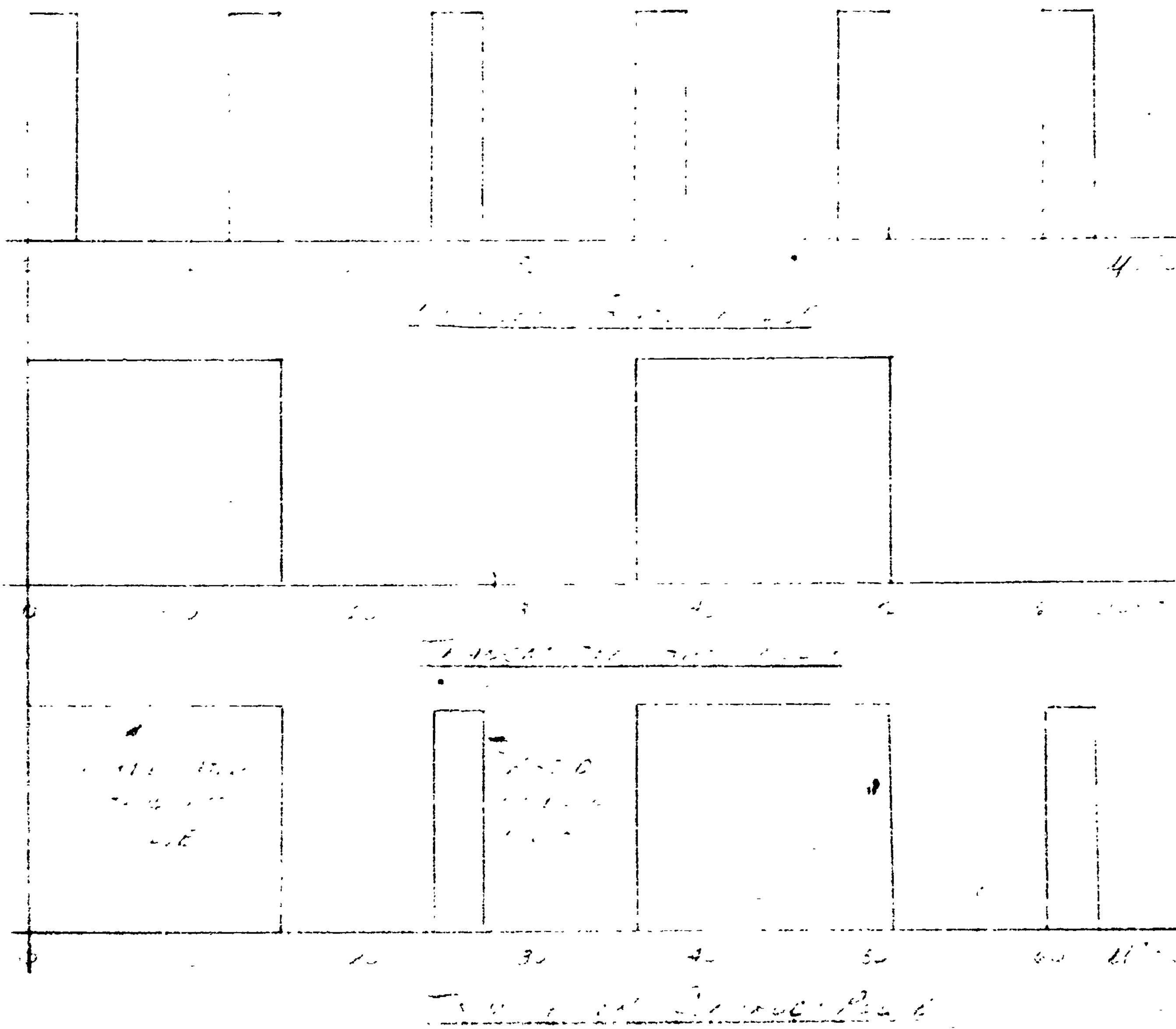


FIGURE 13

DISPOSITION CODE:	1 MAY BE REWORKED	3 CANNOT BE REWORKED
	4 NEW SHOP PRACTICE	5 PARTS MADE ON

REV SYM	DESCRIPTION	EFF
	RECORD RELEASE	

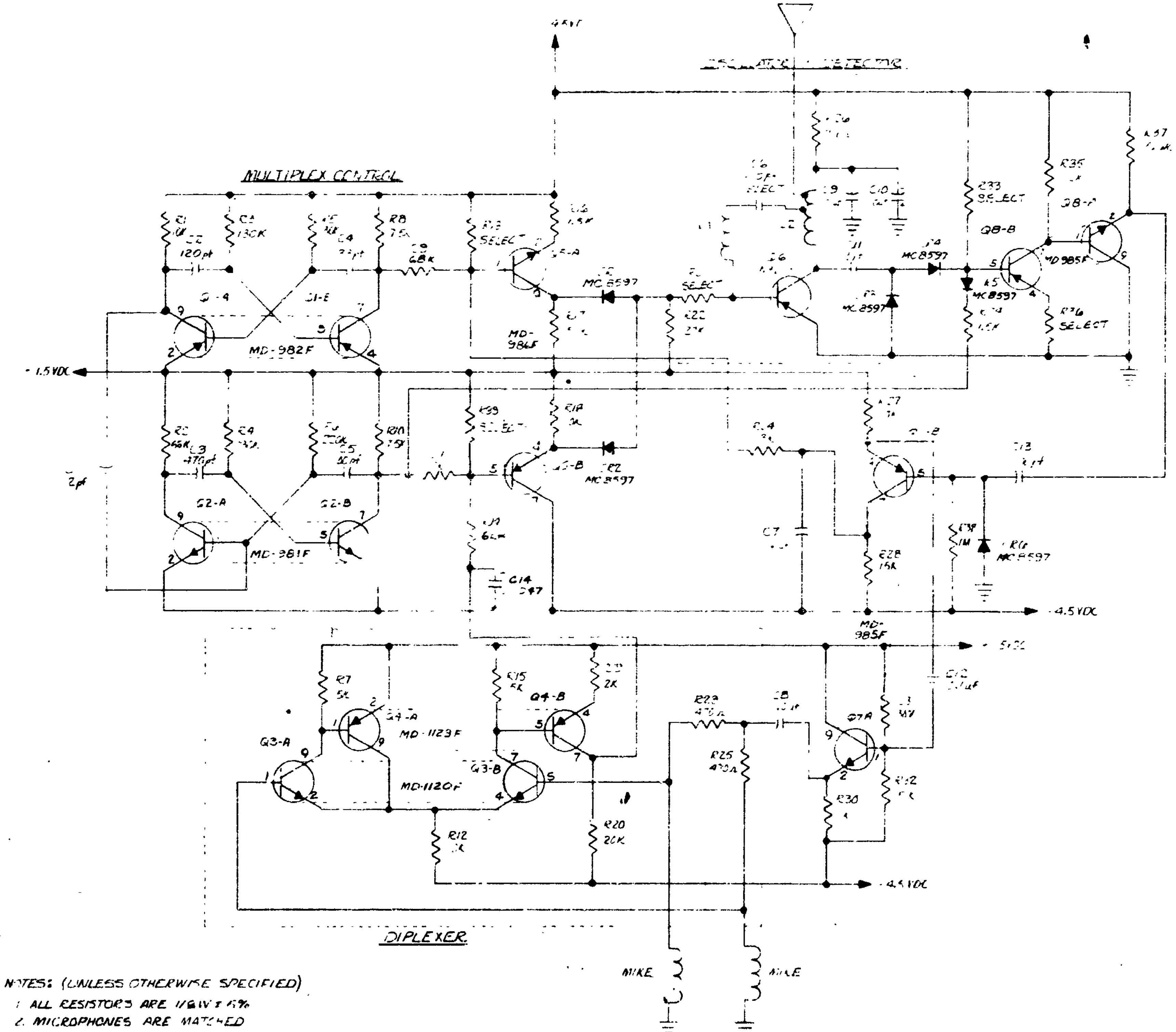


FIG 14

NOTES: (UNLESS OTHERWISE SPECIFIED)
1. ALL RESISTORS ARE 1/8W ± 5%
2. MICROPHONES ARE MATCHED

LAST SYMBOL USED	SYMBOLS NOT USED
Q8	
R39	
C14	
CR6	
L2	

QTY PER ASSY	ITEM	PART NO	DESCRIPTION	MATL	MATL SPEC

LIST OF MATERIAL

SCHEMATIC DIAG. EARMIKE TRANSCEIVER

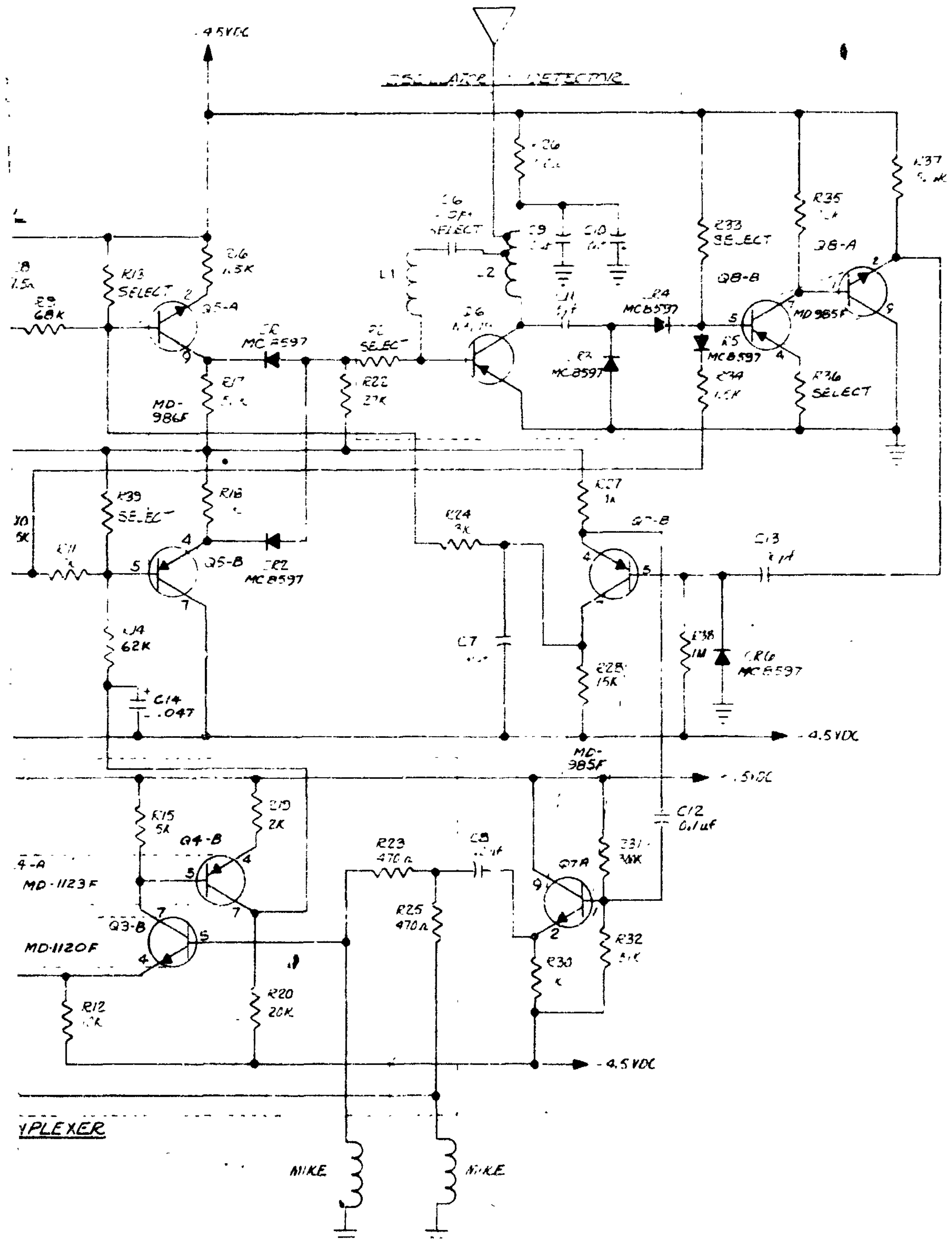


FIG 14

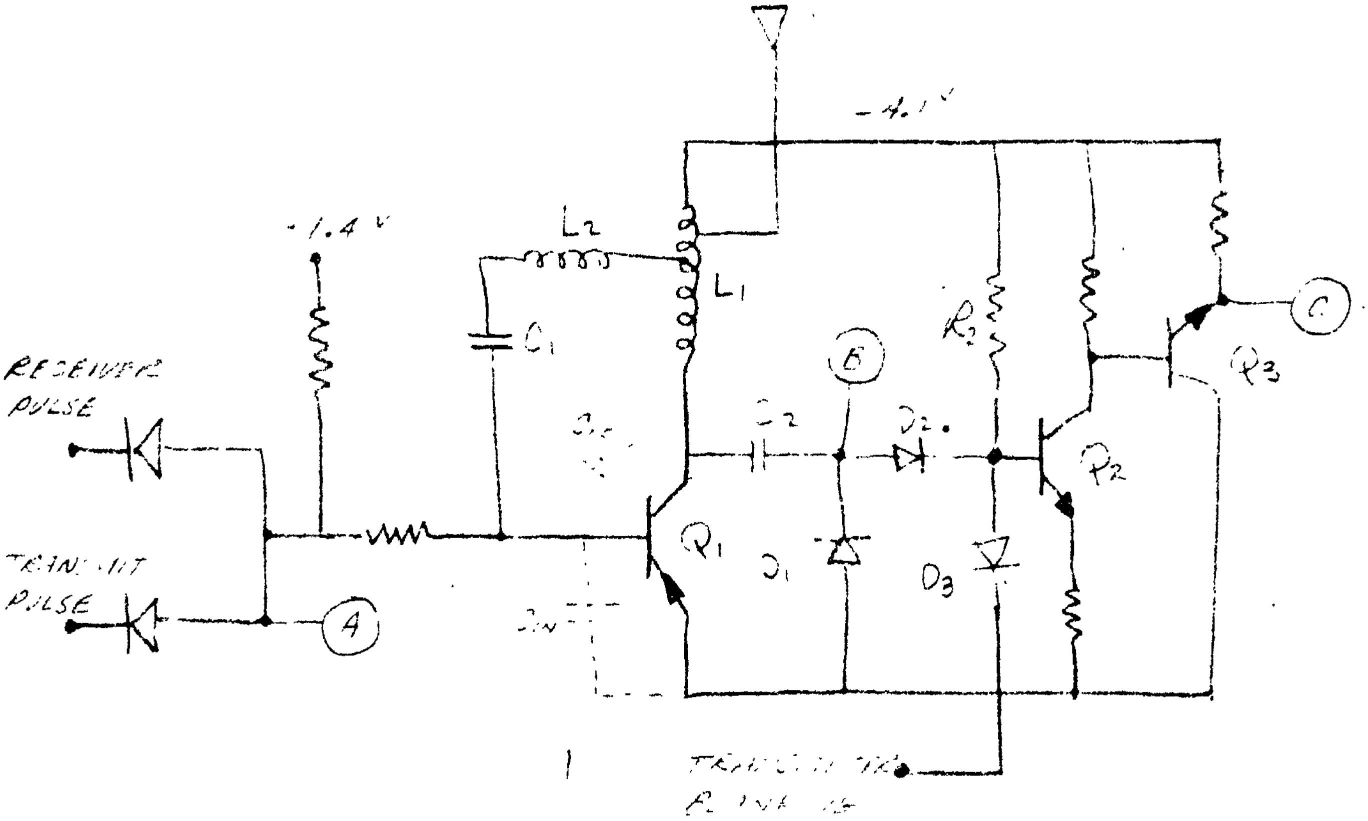
LAST SYMBOL USED	SYMBOLS NOT USED
Q8 R39 C14 CR6 L2	

RECORD RELEASE

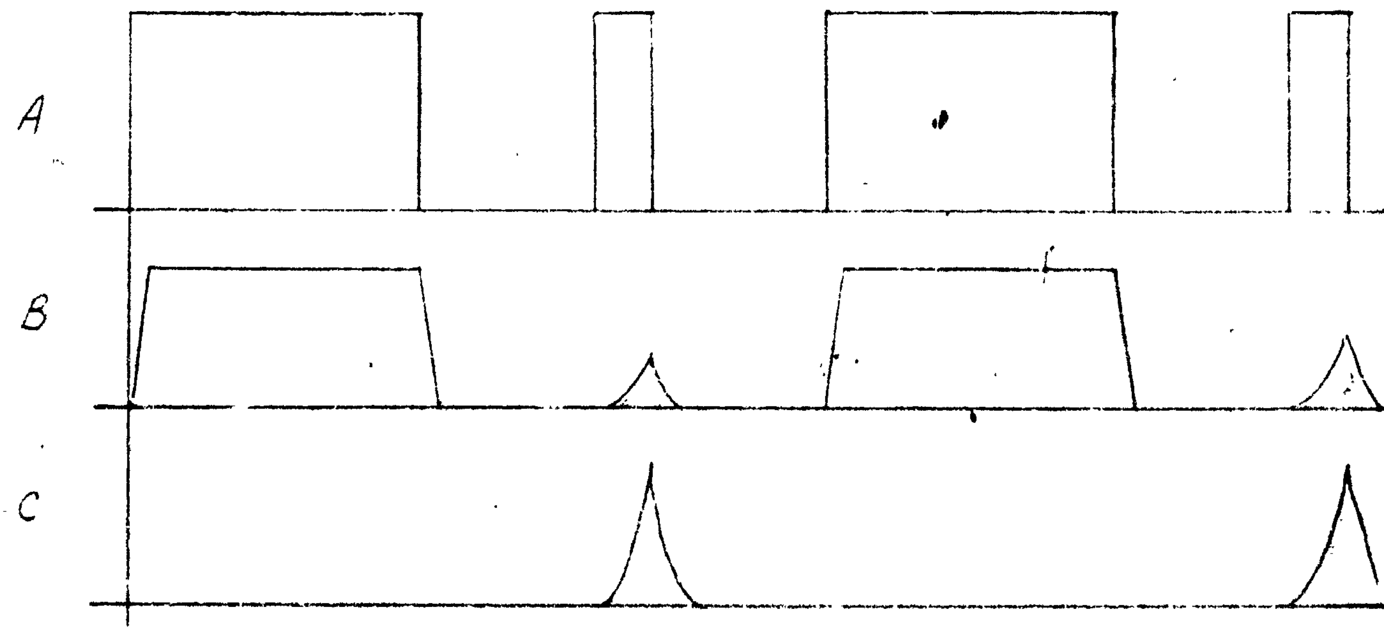
SCHEMATIC DIAG.
EARMIKE
TRANSCEIVER

Spacelabs, Inc.
15521 LANARK ST.
VAN NUYS, CALIFORNIA

102953



Transceiver Circuit



Typical Waveforms in Transceiver

FIGURE 15

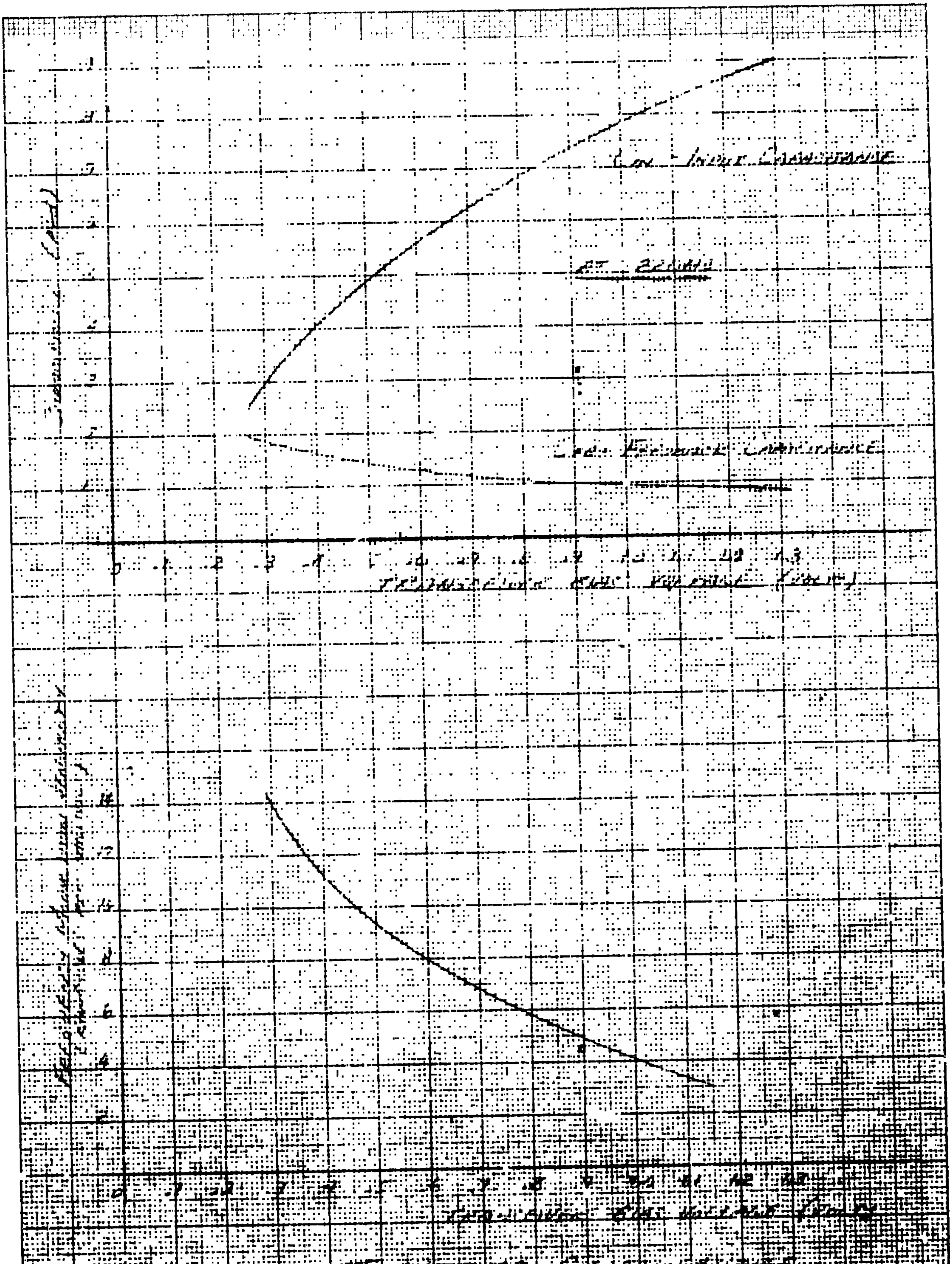


FIGURE 16

The transmission mode is pulsed FM due to these variations. The important characteristics of the oscillator are the rise and fall time of the RF. This is determined by the "Q" of L_1 and L_2 in conjunction with the gain of the transistor which is function of bias. The rise and fall time of the ear mike design is two microseconds.

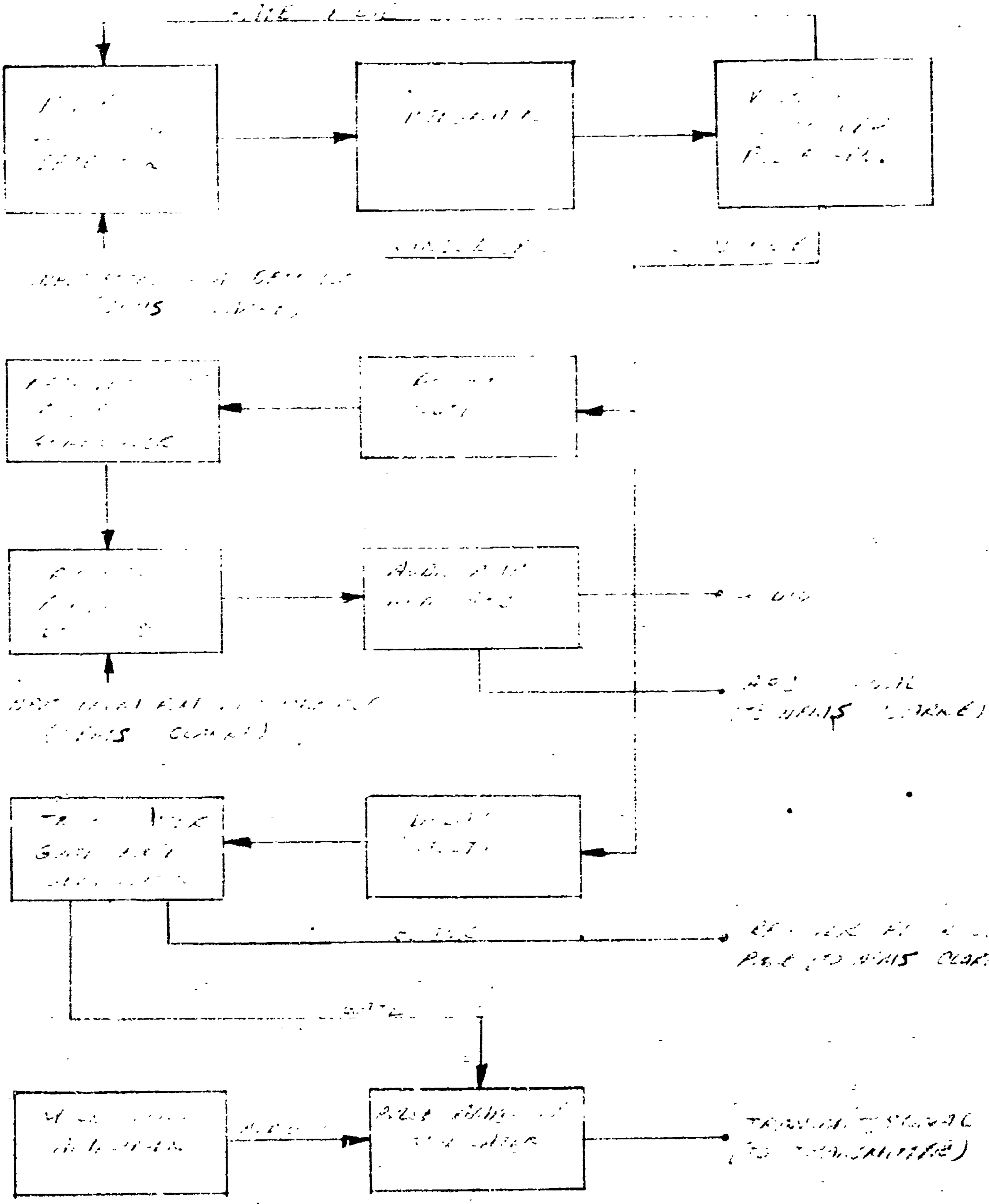
The super-regenerative receiver operates in a similar manner to the transmitte except that full buildup of the oscillator is not permitted. When the oscillator bias is switched on by the receiver gate pulse the buildup of RF oscillations starts from the initial energy in the circuit mainly stored in L_1, L_2, and C_1. If a signal is not present in the antenna the buildup starts on noise in the circuit. The oscillator rise time is independent of the initial energy, hence, the energy in the circuit a short time after the start of oscillation (say one time constant) is only a function of the initial energy. The super-regenerative principle is based on this fact plus the large power gain due to the buildup of oscillations.

An illustration of power gain can be seen by considering a 3 db variation of energy at the start of oscillation vs. the 3 db variation one time constant later. A final value of oscillator power is assumed at 1 mw (0 dbm) and the sensitivity of the receiver is 30 microvolts (-77 dbm into 50 ohm). A 3 db variation at -77 dbm represents a power change of 2×10^{-8} mw. A 3 db variation at -3 dbm (approx. one time constant) is 0.5 mw. This represents a power gain of:

$$Pg \doteq \frac{0.5}{2 \times 10^{-8}} \doteq 25 \times 10^{6}$$

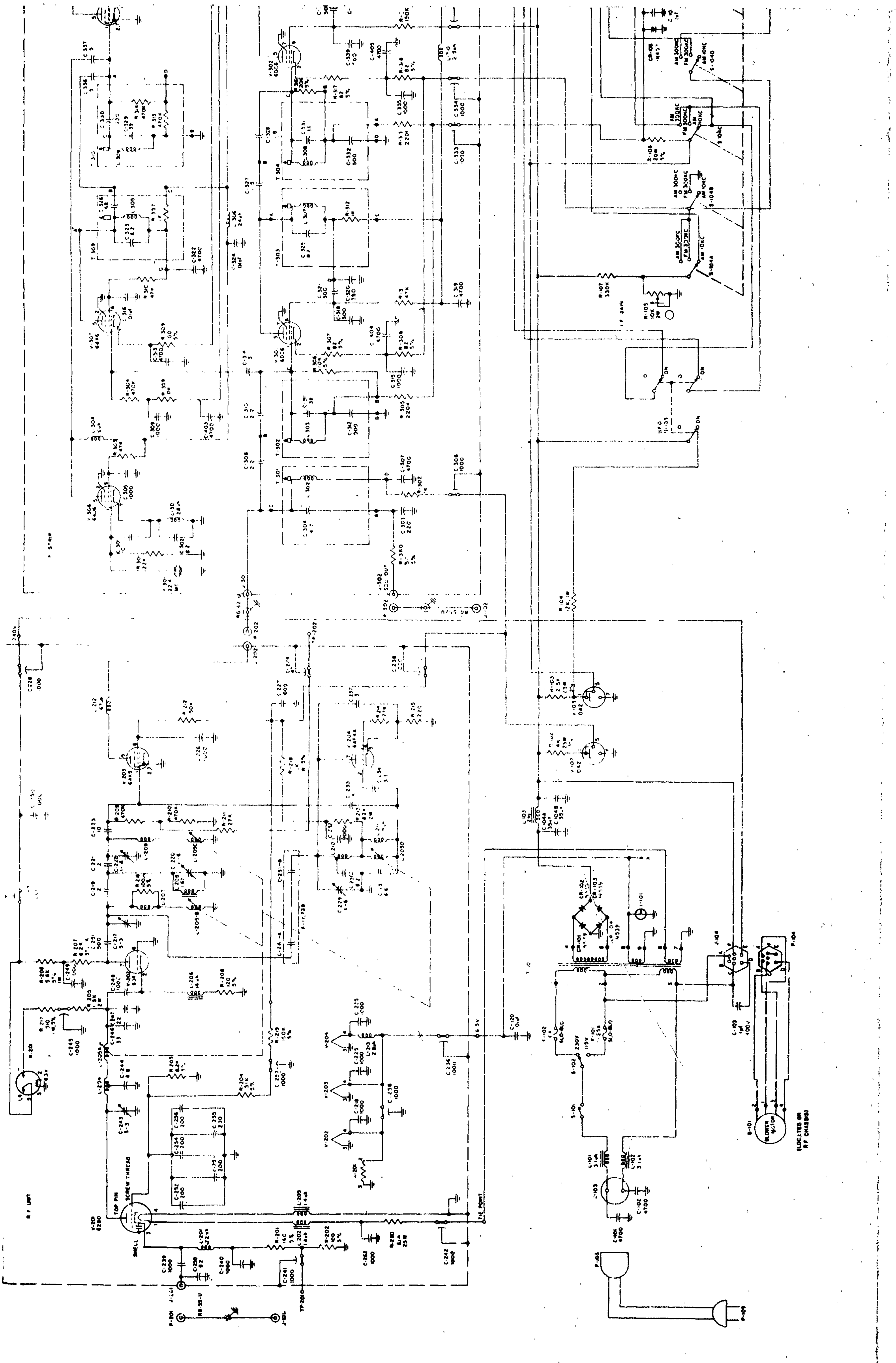
$$\doteq 74 \text{ db}$$

This is the principle that the transceiver receiver function operates. A blanking pulse is used to eliminate the transmitter energy from the detector (C_2 and D_1).

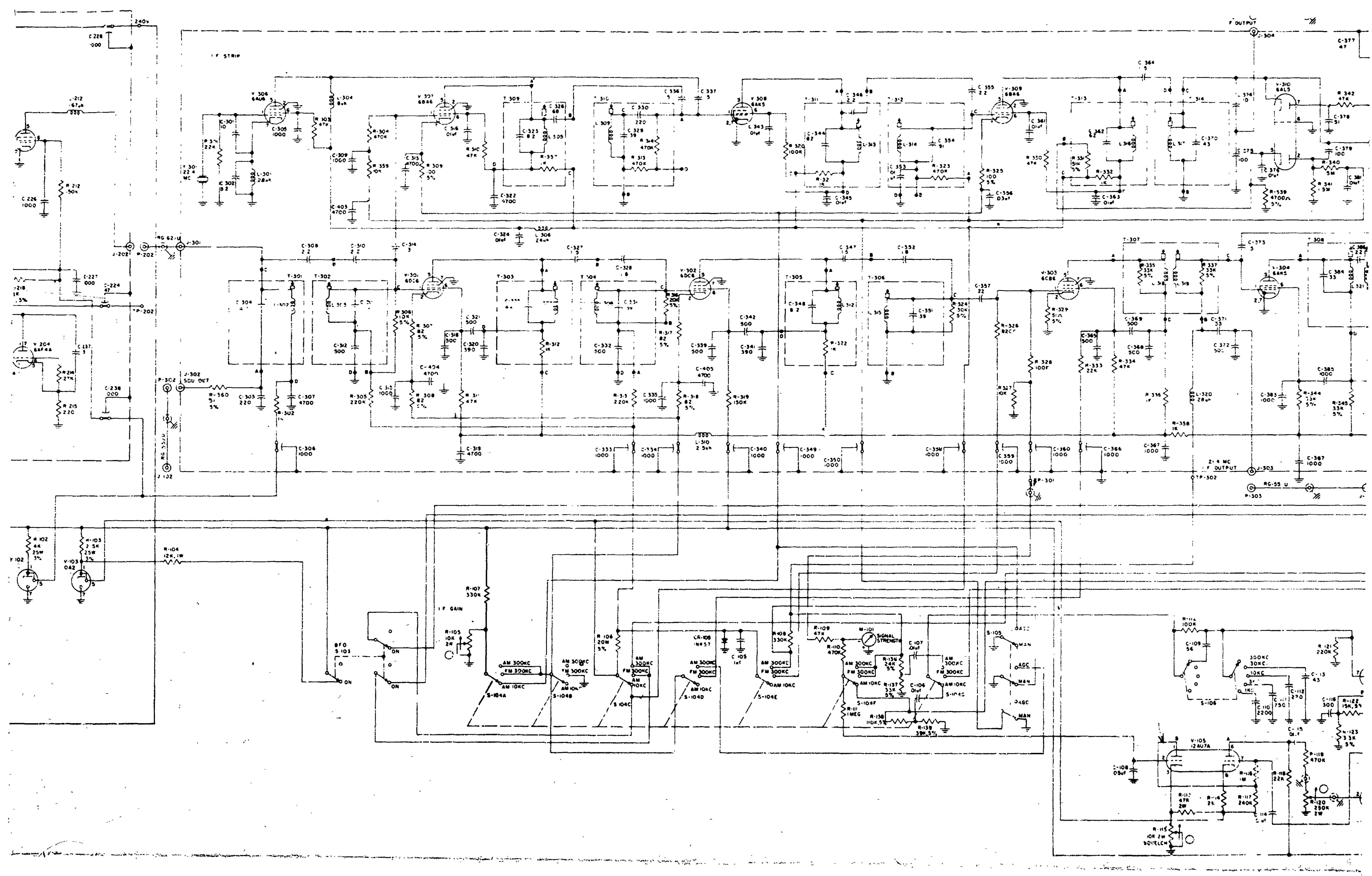


Block Diagram of Ear Mike Modem System

Figure 17



RF UNIT
IF STRIP
BLOWER MOTOR
(LOCATED ON RF CHASSIS)


I F STRIP
I F GAIN
SIGNAL STRENGTH
BFO
SQUELCH

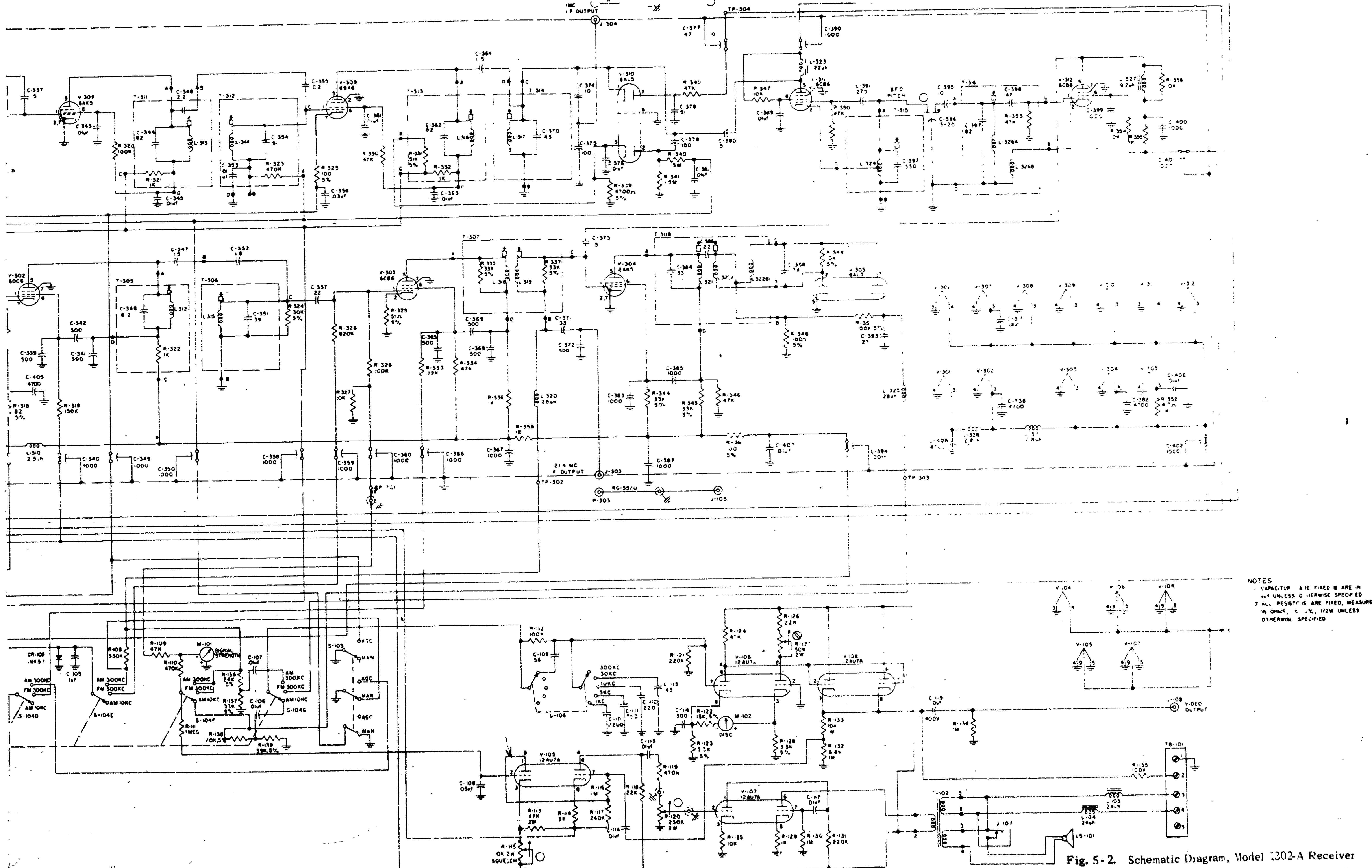


Fig. 5-2. Schematic Diagram, Model 1302-A Receiver

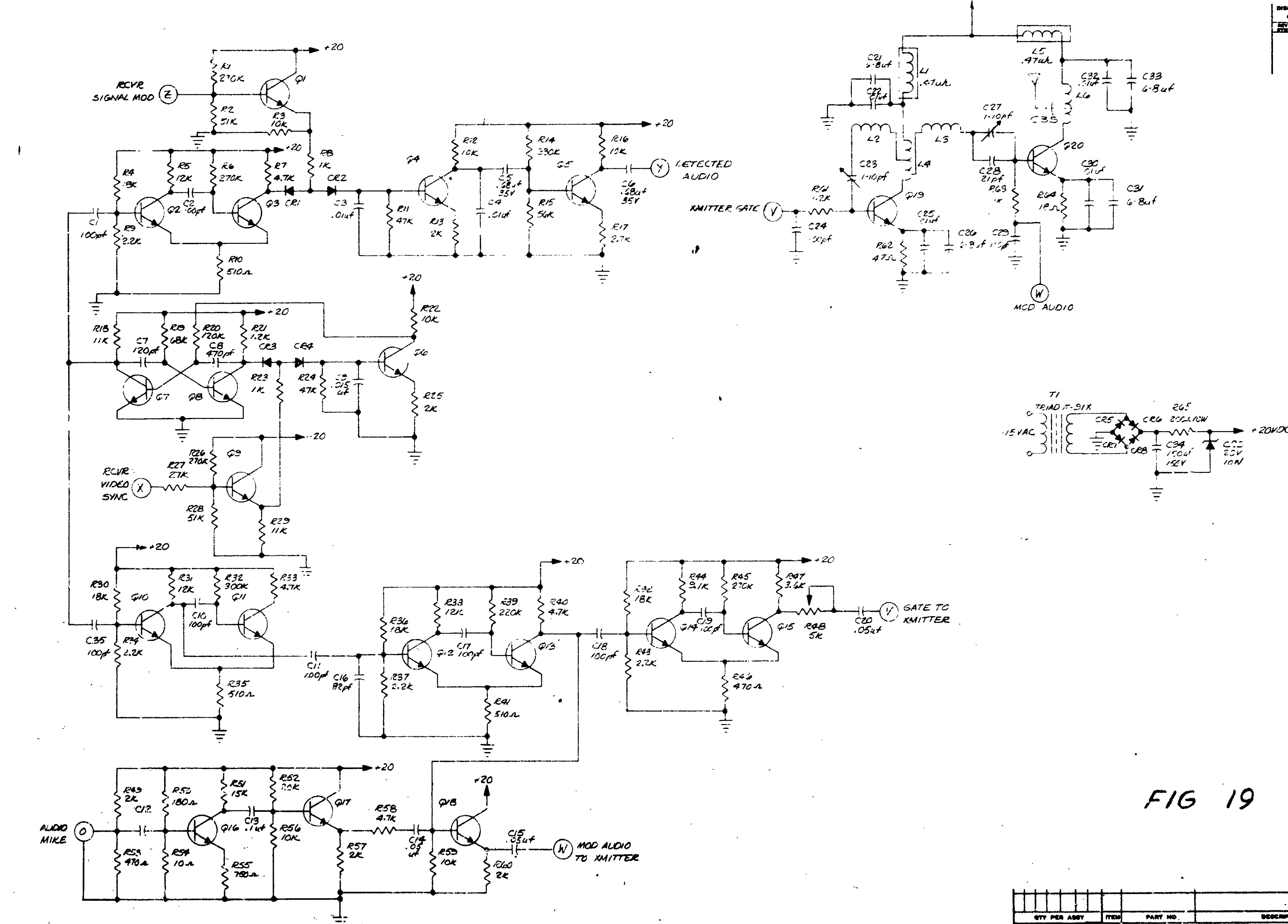


FIG 19

DISPOSITION CODE:	1 MAY BE REWORKED	2 CANNOT BE REWORKED
	4 NEW SHOP PRACTICE	5 PARTS MADE IN

REV	DESCRIPTION	MFG EFF
	RECORD RELEASE	

QTY PER ASSY	ITEM	PART NO.	DESCRIPTION	MATL	MATL SPEC	ZONE

LIST OF MATERIAL

SCHEMATIC DIA
EARMIKE MASTER
STATION ELECTRONICS

DIS	ITION	1 MAY BE REWORKED	3 CANNOT BE REWRKD	5 RECORD CHANGE
CODE:		4 NEW SHOP PRACTICE	6 PARTS MADE OK	
REV SYM	WORD CODE	DESCRIPTION	MFG EFF	APPROVAL & DATE
		RECORD RELEASE		10/8/69

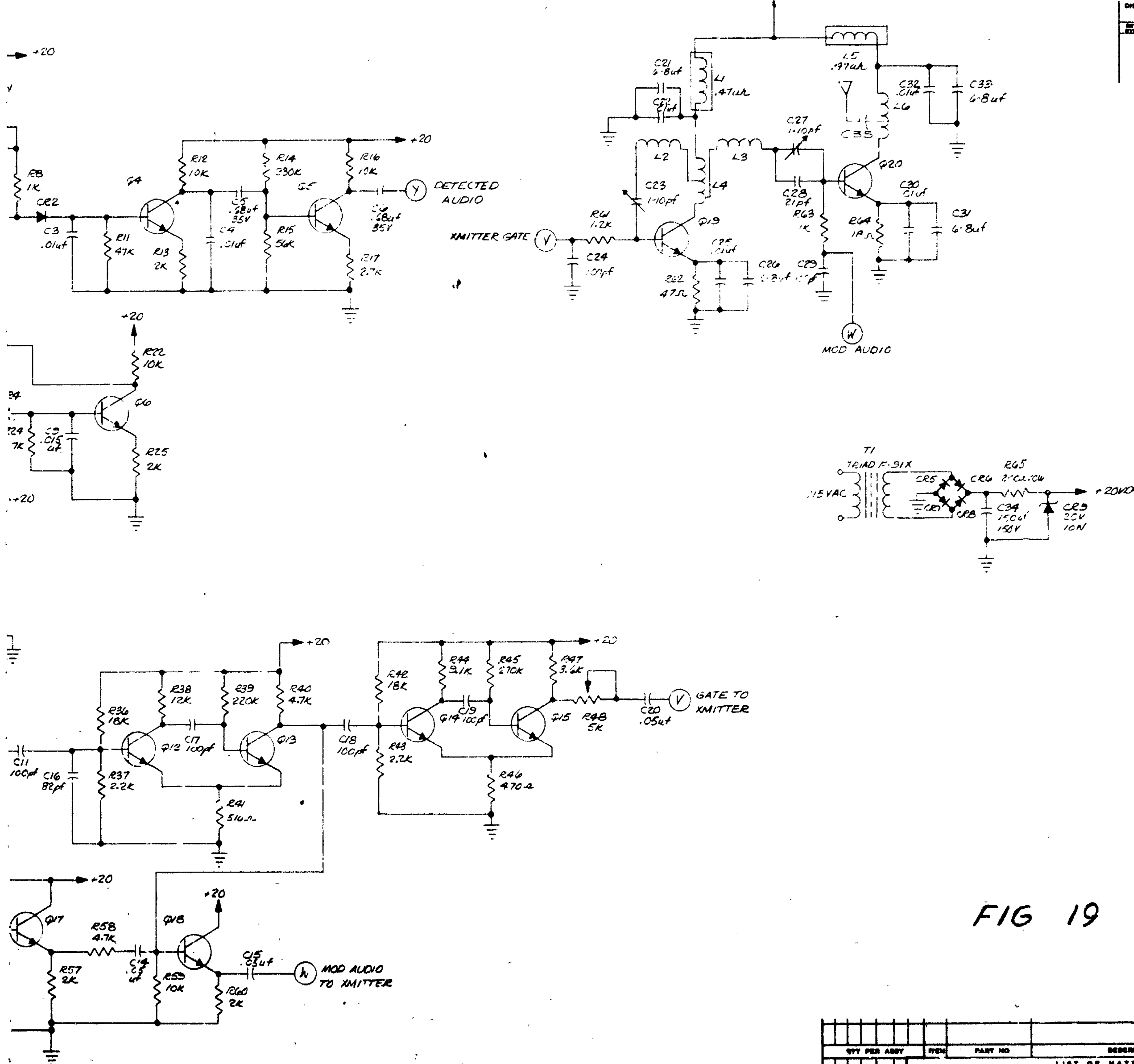


FIG 19

QTY PER ASSY	ITEM	PART NO	DESCRIPTION	MATL	MATL SPEC	ZONE

LIST OF MATERIAL

DRAFT	SCHEMATIC DIA EARMIKE MASTER STATION ELECTRONICS	Spacelabs, Inc. 15521 LANARK ST. VAN NUYS, CALIFORNIA
DESIGNER		
CHECKED		

A negative pulse coupled through D_3 and D_2 saturates D_1 as an efficient detector. This also loads the oscillator by placing C_2 effectively to ground which decreases the Q of the collector circuit and increases the rise time. During the receive cycle a small amount of bias is provided across D_1 through D_2 and R_2 which optimizes the detector efficiency. The detected receiver pulse is amplified in Q_2 and Q_3 to a proper level for detecting the audio.

The receiver is controlled by an AGC loop. The AGC voltage is derived by detecting the average received pulse amplitude and controlling the amplitude of the receiver gate which varies the gain of the super-regenerative detector. The time constant of the AGC loop is 8 milliseconds.

The detected pulse train contains the audio modulation and is detected in a shunt detector with a time constant of 50 microseconds. This provides an audio response of 7 kilocycles. The detected audio is coupled to the diplexer through a low impedance output stage.

F. Master Station Design

The master station design was based on utilizing a standard Nems Clarke Receiver model 1301. Special circuitry was incorporated to provide synchronization, pulse FM detection, AFC, pulse modulated audio and pulse amplitude transmission. A block diagram of these functions is shown in Figure 17 and schematics in Figures 18 and 19.

1. Modifications to Nems Clarke

The Nems Clarke provides AM or FM output. The output was modified to provide both AM and FM outputs simultaneously. This change involved changing the switching functions within the receiver. A second modification to the receiver was to provide A.F.C. capability. A varicap tuning circuit was added to the local oscillator. The RF input bias was also modified to enable a blanking pulse to be injected to prevent overloading of the receiver.

2. Synchronization Circuitry

The synchronization circuitry consists of a pulse coincidence detector, an integrator and a voltage controlled pulse generator (vco). The theory of operation of the sync. circuit is identical to that of a phase lock loop except that pulses are used instead of pure sine waves. The frequency of the voltage controlled pulse generator is set slightly lower than the expected receiver pulse frequency. When the receiver pulse from the AM channel is compared in the coincidence detector the error between the pulse positions changes (increases) the voltage controlled pulse generator frequency. The loop thus locks and tracks the incoming pulse leading edge to provide time synchronization. The timing relationships were previously shown in Figure 4.

3. Pulse FM Detector

The FM output from the master station is a pulse with an amplitude as a function of frequency due to the discriminator characteristic. The pulse is gated in the audio detector to demodulate the audio data. The gate pulse is generated from the sync pulse with a delay multi to assure the proper time relationship. The detected audio is amplified and fed to the speaker amplifier in the Nems Clarke receiver.

4. <u>Automatic Frequency Control</u>

The detected audio is amplified and filtered to provide a frequency control signal. This DC signal controls the bias on the varicap in the Nems Clarke local oscillator which controls frequency. The time constant in the A.F.C. loop is 20 milliseconds and the loop gain is 100 with a dynamic range of one megacycle. The A.F.C. action is initiated by tuning on the station and then locks in. A manual position provides a fixed bias to the varicap and permits standard tuning.

5. <u>Pulse Modulator</u>

The pulse modulator drives the transmitter to provide pulsed AM transmission. The pulse timing is established with a pulse delay from the sync pulse. The modulator pulse is 10 microseconds in length and is modulated with audio from the microphone amplifier. The modulation is adjustable from 5% to 50% with the mike gain control.

6. <u>Blanking Pulse</u>

The blanking pulse is generated in coincidence with the modulator pulse. The blanking pulse is injected on the grid of the RF AMP/mixer stage to prevent mixing and amplification of the transmitter leakage energy.

7. <u>Transmitter</u>

The transmitter is a master oscillator and power amplifier utilizing 2N3375 RF power transistors. The oscillator is fixed bias modified clapp type with a matching network to drive the power amplifier. The power output of the oscillator is 100 mw at 220 mc. The gain of the power amplifier is 15 db, hence the average continuous power output is 3 watts.

The modulator pulse biases the power amplifier off except when transmission is desired. The duty cycle of the modulator is 25%, hence a peak power of 3 watt and an average power of 750 mw is provided. The gain of the power amplifier varies with the modulator pulse amplitude, hence the transmitter output is pulsed AM transmission. The transmitter output network is designed for a 50 ohm antenna.

8. Antennas

The master station can be operated with remote ground plane type antennas. The design also includes local antennas. These antennas are extendable rod antennas tuned for a quarter wave length. The antennas utilize the master station case as a ground plane. The patterns for this type antenna provide a gain of 1.7 db in the horizontal direction.

9. Power Supply

The special circuitry is operated for a 20 volt regulated power supply operated in parallel with the Nems Clarke power supply. The regulation and filtering provided holds the 20 volts within 100 mv ripple and transients. The supply is capable of supplying 150 ma at 20 volt. Approximately 70 ma are utilized to drive the special circuitry.

SECTION IV

PACKAGE DESIGN, FABRICATION AND TEST - PHASE II

The package design for the ear microphone was selected on the basis of eventual microcircuit fabrication. The design criteria included constraints on components and parts used, configuration and comfort. The final design, while not micro-circuit, utilizes dense welded construction techniques.

A. Materials and Components

The selection of materials and components was based on the smallest available type to meet the performance requirements. A minimum number capacitors were used in the design and the capacitance values were kept to a minimum. The transistors were the dual "flat pack" configuration except for the single RF transistor which is a TO-18 package. The inductors utilized in the RF design were specially designed spiral type printed circuit inductor. Miniature connector. were utilized throughout.

Microcircuit fabrication techniques were considered. The evidence indicated that miniature technique would be superior at the prototype stage of development. The major factors weighing in favor of this technique were:

1. Less than 100% utilization due to RF package.
2. Utilization of standard components with reliability history.
3. Current availability of components.
4. Ear Mike design was not field proven.
5. Relative ease of modification.

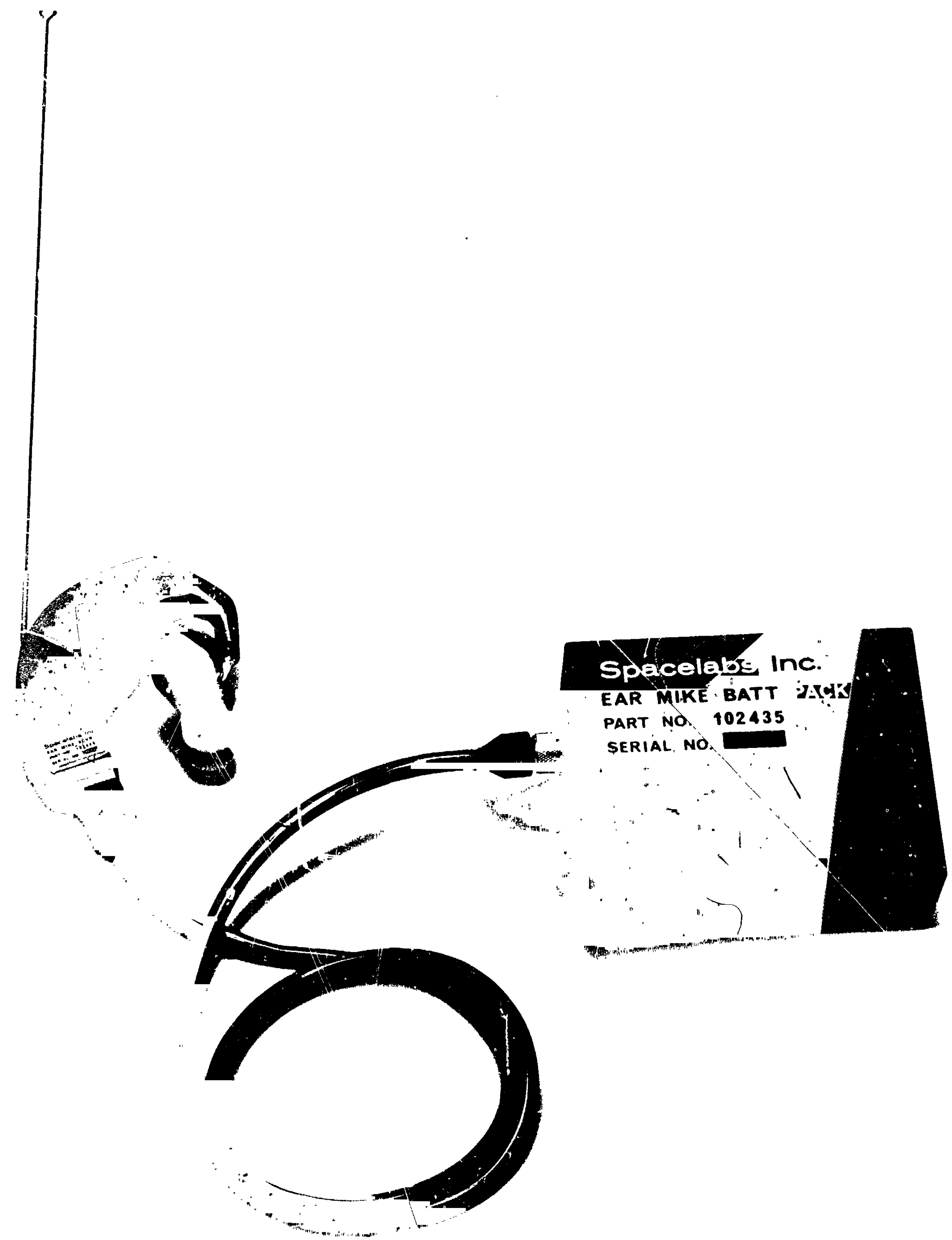
6. A volume reduction of approximately 25% is all that could be expected.

The materials, processes and components utilized in the ear microphone are adaptable to microcircuit fabrication techniques.

B. Configuration

The package configuration selected for the ear microphone was based on an ear mounted assembly and standard miniature packaging techniques. Several models of ear mounted configurations were tested for comfort. The final package configuration is shown in Figure 20. A connector between the transceiver and diplexer/insert was provided to insure an RF configuration and a hard wire configuration. The model of final ear mike was tested on four subjects for a period of 8 hours each. There were no irritations or uncomfortable effects noted during this test. A connector is provided on the bottom of the ear mike for battery input. Available batteries do not have the proper configuration for incorporation on the ear mounted assembly. The connector was provided to adapt to an ear mounted battery pack at a future date.

The diplexer and insert are connected together with flexible leads which are also the microphone signal wires. The microphones are mounted together in the insert with one loaded into an acoustical loading cavity. The second microphone is coupled into the silicon ear insert. The insert was designed to fit a large variety of ear configurations and was tested on several subjects for comfort. Some irritation was noted after 4 to 6 hours on one subject. The insert did slightly bind on the rear of the ear. The other subjects tested had no significant irritation or comfort problems over an 8 hour period.


Spacelabs Inc.
EAR MIKE BATT PACK
PART NO. 102435
SERIAL NO. [redacted]

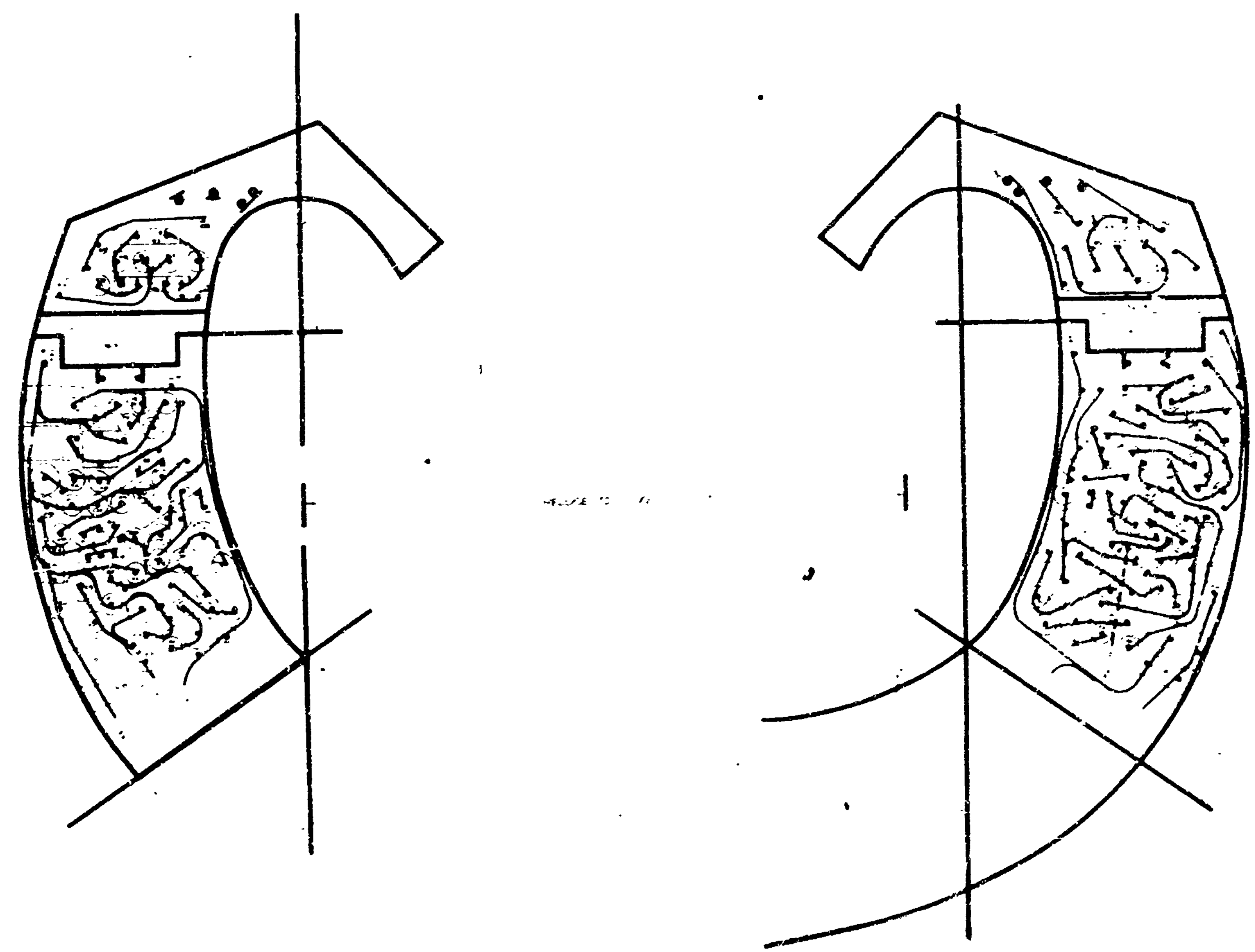
An 8 to 10 inch rod antenna was provided with the transceiver to assure performance at greater than 100 yards. Several experiments were conducted with integral antennas with success up to 50 yards but marginal performance at 100 yards.

C. Electronic Package Design

The electronic package design, exclusive of the RF package is standard welded circuit techniques. The layout of components is shown in Figure 21. The parallel mylars are .280 inches apart and all components mounted between. The component interconnections are made with .015 nickel ribbon. The connectors are multi-pin cannon subminiature type with a separation stress of 2 lbs. per pin. All transistors are the 6 lead "flat pack" type. Low k ceramic capacitors are used in all values up to .022 microfarads. Tantalum capacitors were used for larger values.

D. RF Package Design

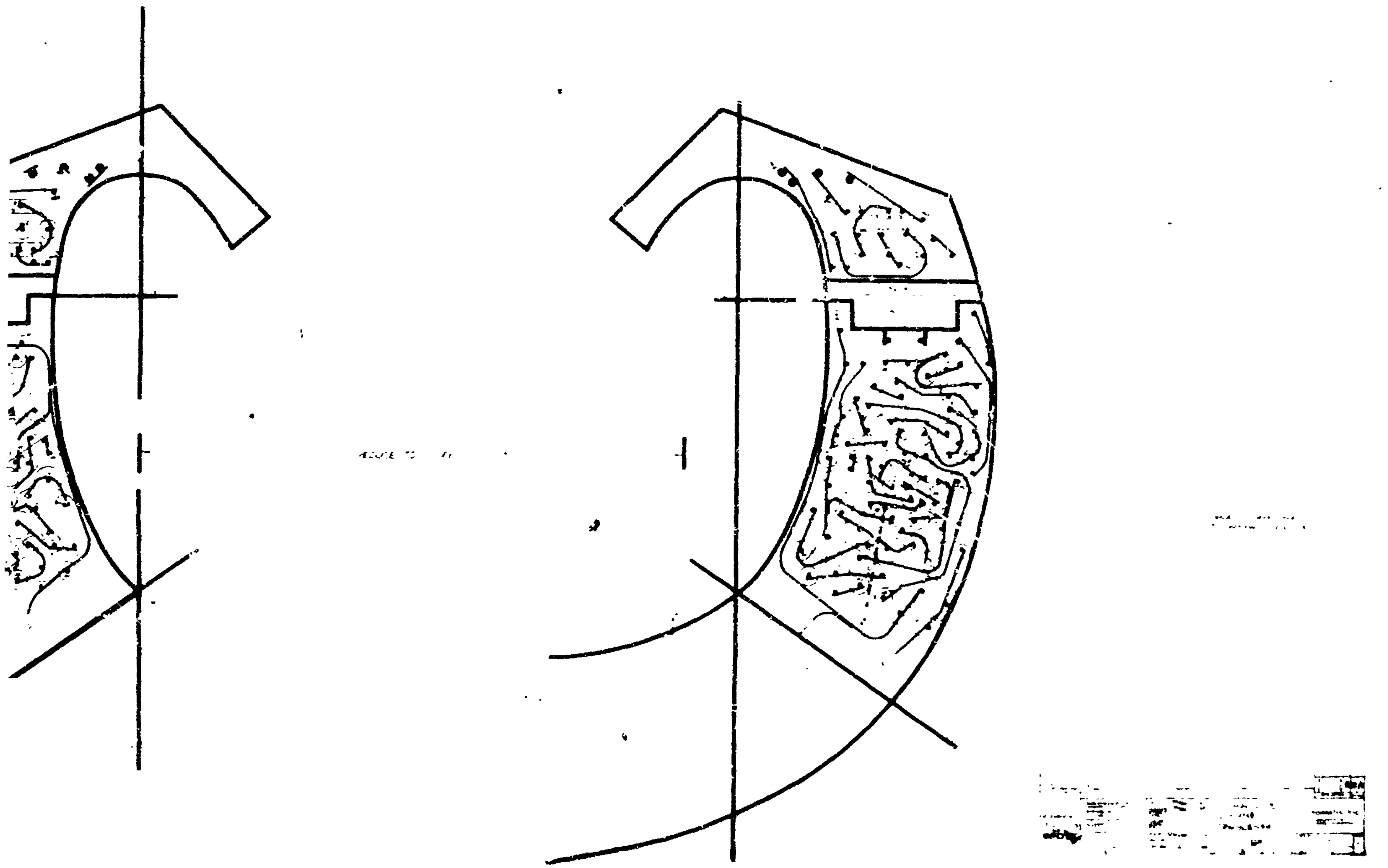
The transceiver RF section was packaged with a 3 dimensional technique shown in Figure 22. The inductors L_1 and L_2 are flat printed spiral type measuring 0.5" x 0.5". The inductors are mounted parallel on a base plate that carries the power supply leads and provides a ground plane. The transistor (TO-18 isolated case) is mounted to the ground plane. The base and collector leads are connected to L_2 and L_1 respectively. The emitter lead is connected to ground. The bias resistor, detector capacitor and detector diode, are mounted to the forward header in the package. The tuning capacitor is mounted to the base plate between the coils. The outside surface of the coils are shielded with ground planes to prevent interaction between the body and tuning coils.



EARMIKE TRANSCEIVER COMPONENT LAYOUT

FIG. 21

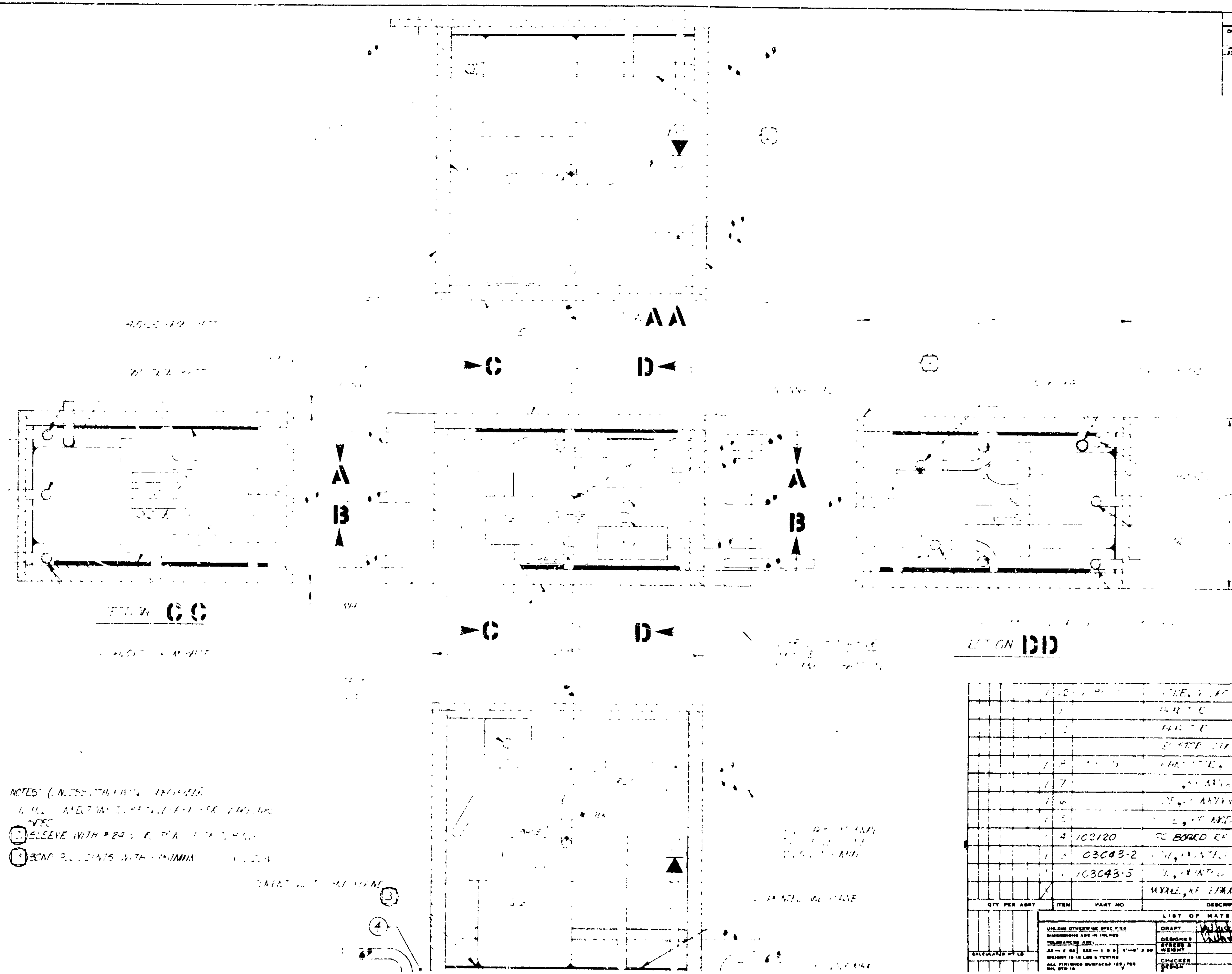
Spacelabs Inc. 15521 LANARK ST.,



EARMIKE TRANSCEIVER COMPONENT LAYOUT

FIG. 21

REVISIONS		
DISPOSITION CODE	DESCRIPTION	
	DEVELOPMENTAL RELEASE	



NOTES: UNLESS OTHERWISE SPECIFIED

SLEEVE WITH #24 ...

BOND ... WITH ...

FIG 22

QTY PER ASSY	ITEM	PART NO	DESCRIPTION	MATL	MATL SPEC
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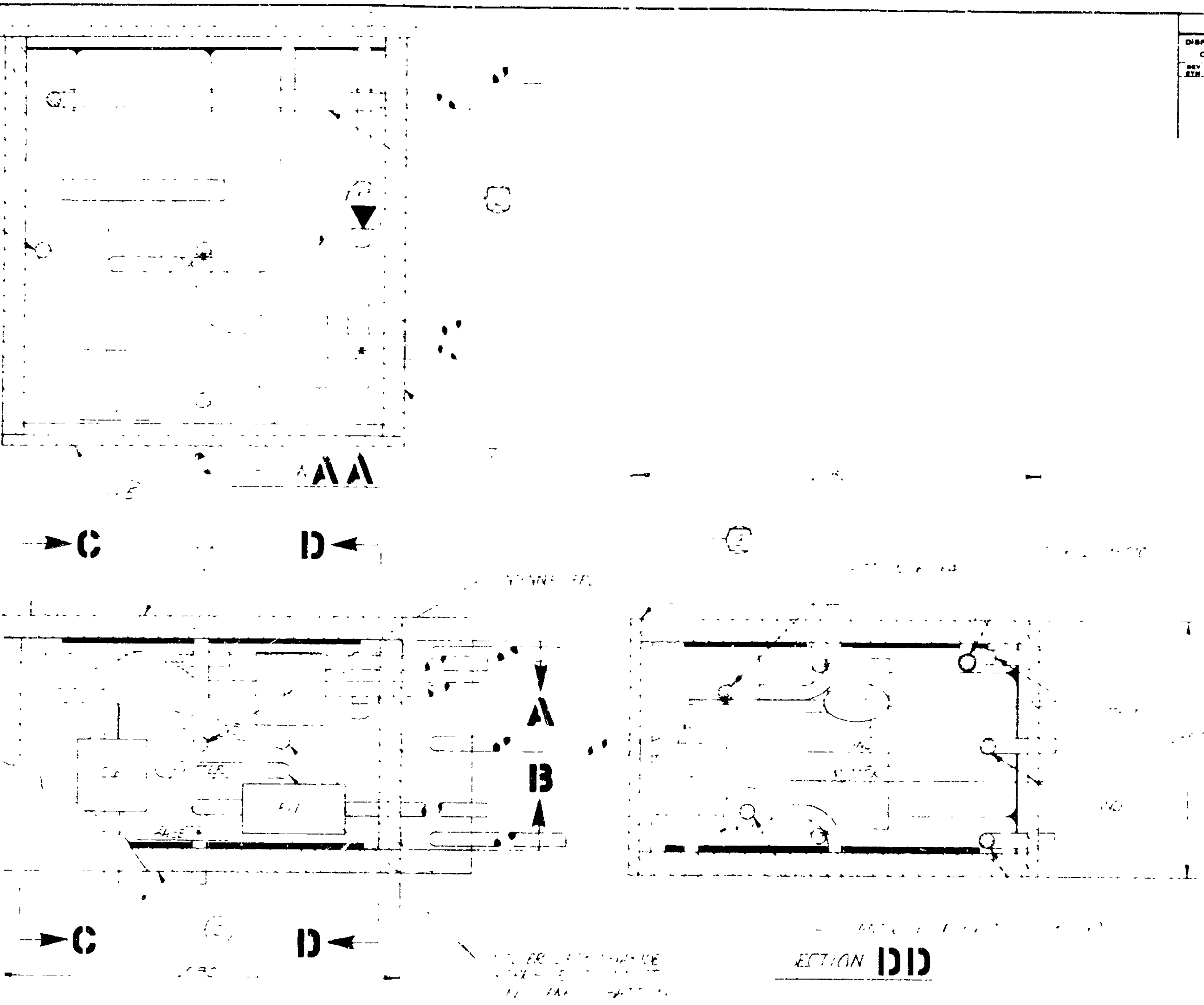
			[illegible]		[illegible]
			[illegible]		[illegible]
			[illegible]		[illegible]
1	8	[illegible]	[illegible]		[illegible]
1	7		[illegible] ANGLE		
1	6		[illegible] ANGLE		
1	5		[illegible] ANGLE		
	4	1C2120	PC BOARD RF MODULE		
1		03C43-2	[illegible]		-2
		1C3C43-5	[illegible]		-1
			MODULE, RF [illegible] ASS'Y		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DRAFT | DESIGNER | STRESS & WEIGHT | CHECKER | DESIGN

TITLE: RF MODULE ASS'Y



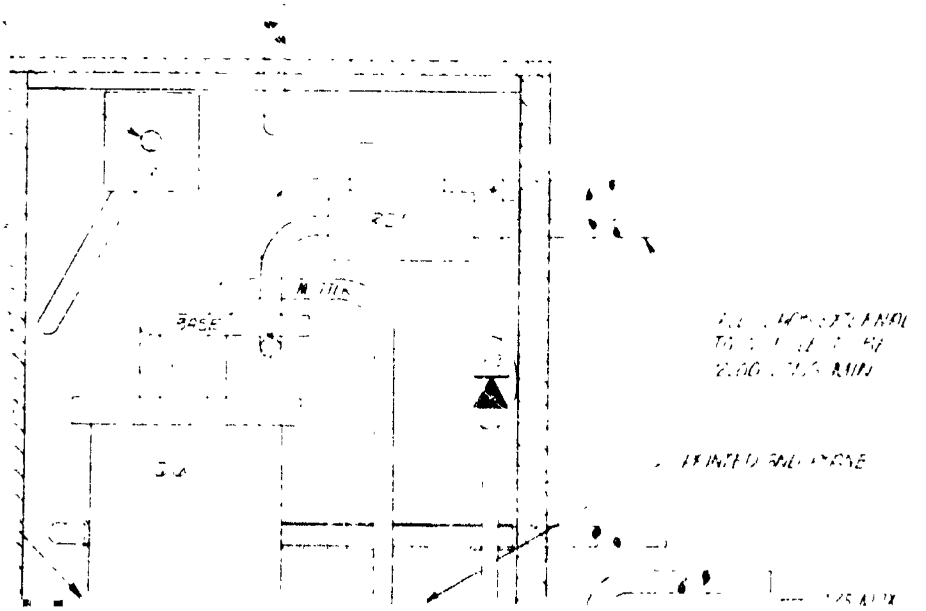


FIG 22

REVISIONS

REV LTR	WORD CODE	DESCRIPTION	MFG EFF	PART	ASSY	APPROVAL & DATE
		EXPERIMENTAL RELEASE				[illegible]

LIST OF MATERIAL

QTY PER ASSY	ITEM	PART NO	DESCRIPTION	MATL	MATL SPEC	ZONE
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1	11		[illegible]			
1	10		[illegible]			
	9		[illegible]		[illegible]	
1	8	[illegible]	[illegible]			
1	7		[illegible] MODULE			
1	6		[illegible] MODULE			
1	5		[illegible] MODULE			
1	4	102120	PC BOARD RF MODULE			
1	3	103C43-2	[illegible], PAINTED			
1	2	103C43-5	[illegible], PAINTED			
			MODULE, RF EXAMPLE ASS'Y			

TITLE: RF MODULE ASS'Y

Spacelabs, Inc.
15831 LANARK ST
VAN NUYS, CALIFORNIA

E. Ear Mike Fabrication

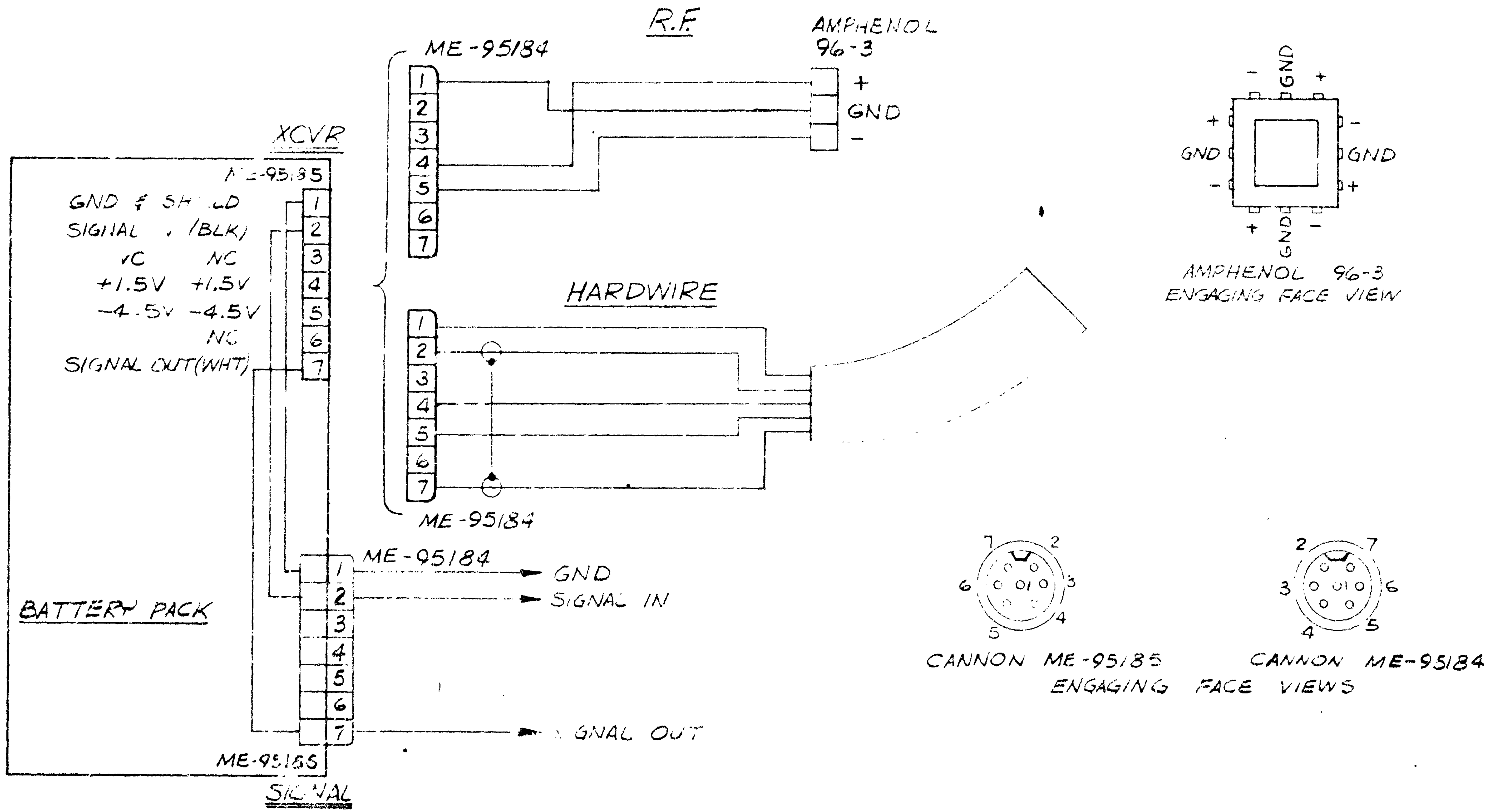
The ear mike electronics was fabricated in a welding jig. The jig aligns and holds the mylars for welding. The components were loaded and the mylars compressed to the 0.280 spacing. The welds were made in accordance with the layout and weld schedules for the leads. Prior to cutting the excess leads the electronics was tested. After test the electronic unit was freeze coated.

The RF unit was built up with welding and solder construction in accordance with the layout and attached to the electronics for test. The connector between the transceiver and diplexer was captive, hence only RF tests were conducted. After the RF test the assembled ear mike was mounted in the molding jig and the excess leads were cut. The unit was potted with clear stycast and baked for 24 hours. Prior to potting a dam was built between the connectors to assure separation. The unit was separated and finished to size. The ear mike was tested prior to painting and labeling. The ear mike insert was attached and complete tests conducted.

The hard wire configuration required a dummy section to replace the transceiver This section was cast and finished exactly as the transceiver. The units were painted and labeled after test. A wiring diagram is shown in Figure 23.

F. Master Station Fabrication (Figure 24.)

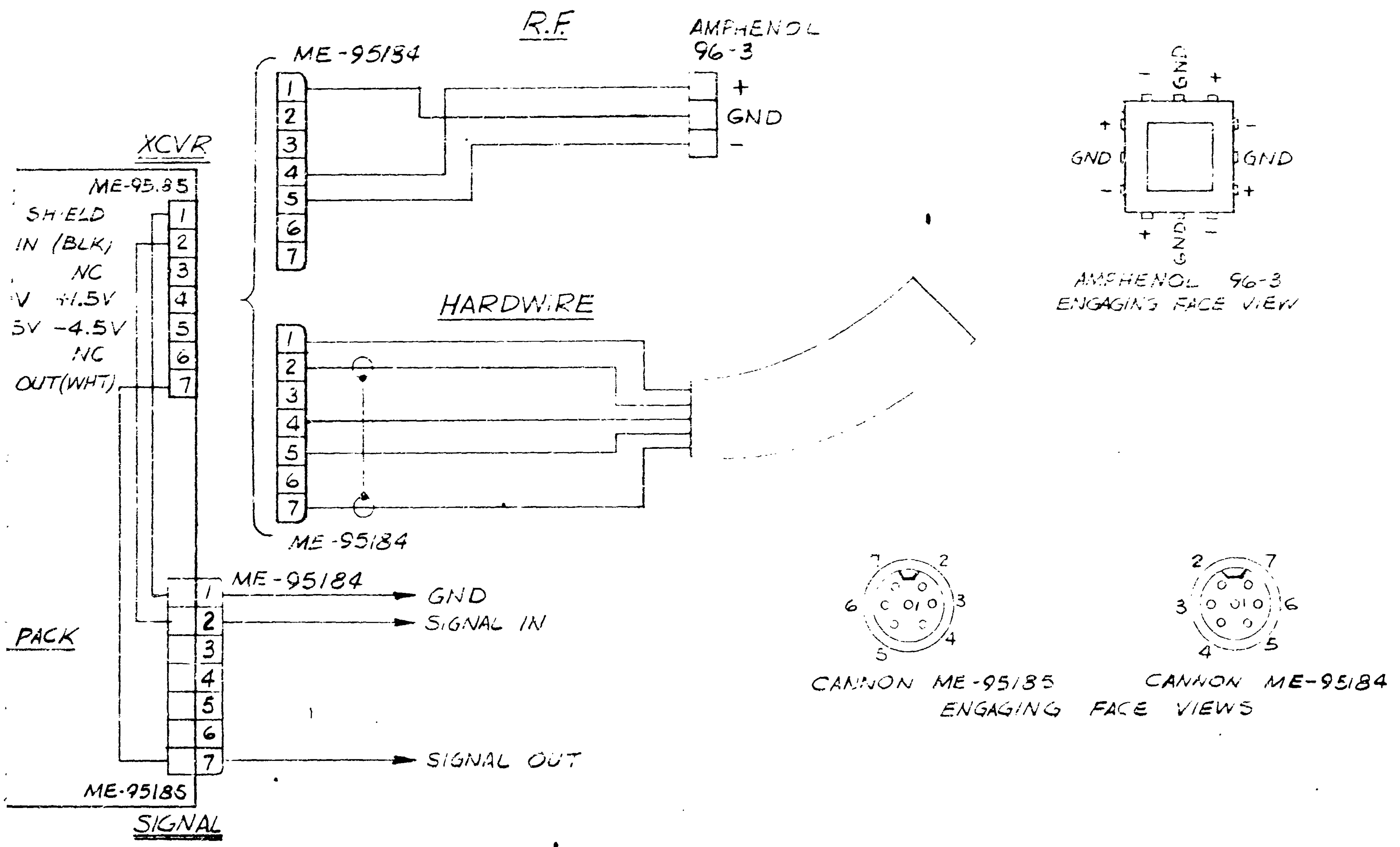
The master station was designed to mount in a special case with an auxiliary equipment drawer. The special circuitry was mounted on the receiver chassis. All special circuitry was fabricated with three standard 4 x 5 boards and termina board construction. Transistors are mounted in sockets and the power regulator is mounted to a heat sink.



EARMIKE WIRING DIAGRAM

FIG. 23

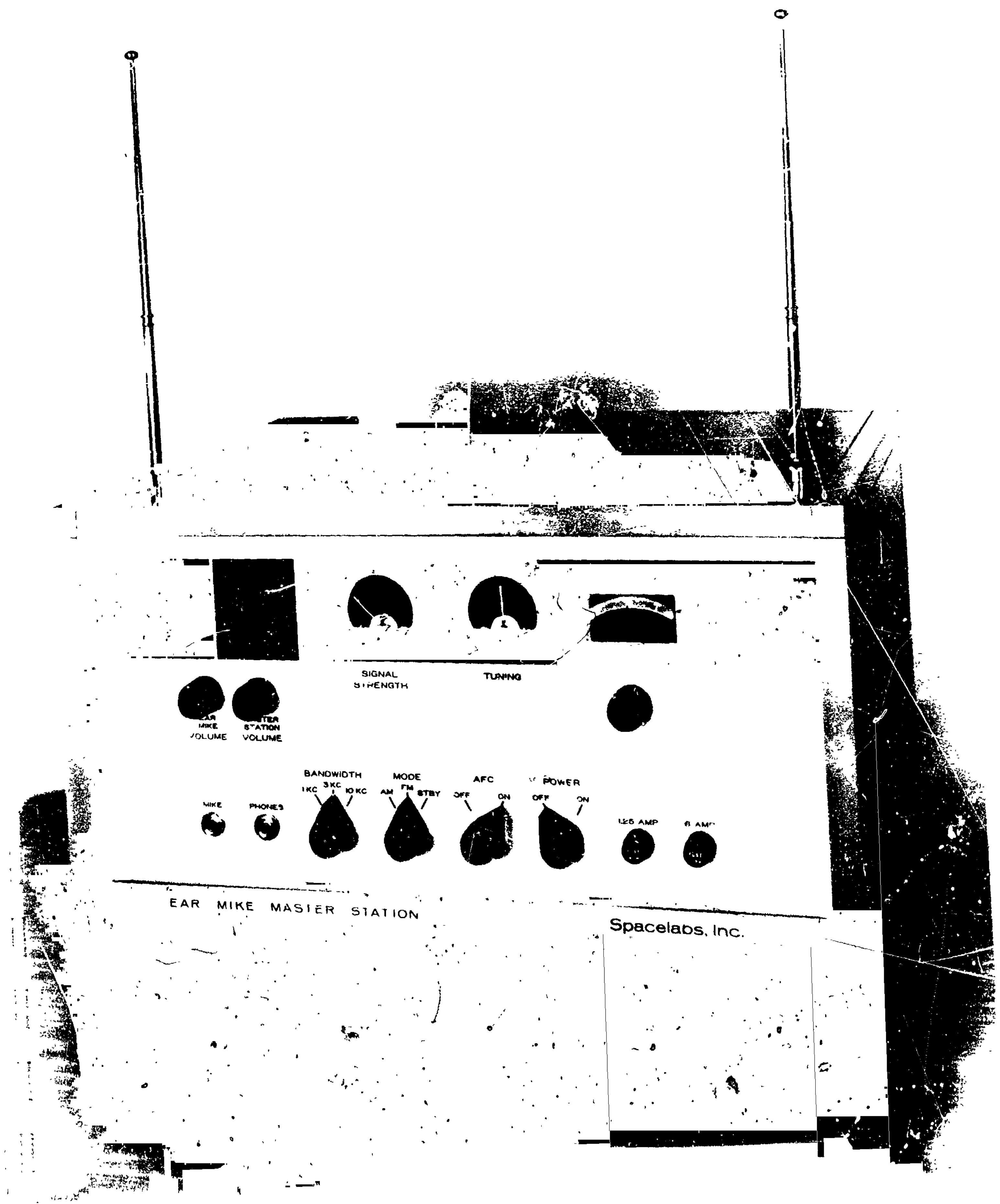
Spacelabs, Inc. 15521 LANARK ST., VAN NUYS, CALIFORNIA DWG NO 102



EARMIKE' WIRING DIAGRAM

FIG. 23

Spacelabs, Inc. 15521 LANARK ST., VAN NUYS, CALIFORNIA 102433



SIGNAL STRENGTH
TUNING
VOLUME
STATION VOLUME
BANDWIDTH
1KC
3KC
10KC
MODE
AM
FM
STBY
AFC
OFF
ON
POWER
OFF
ON
MIKE
PHONES
EAR MIKE MASTER STATION
Spacelabs, Inc.

The RF transmitter is packaged in a shielded box with terminal wiring construction. A shield was necessary between the master oscillator and power amplifier to prevent feedback. The transistors are mounted in heat sinks to the shield. The power and input leads are coupled in with feedthrough capacitors. The transmitter output is fed with a 50 ohm line to a BNC connector on the receiver chassis.

The receiver assembly is mounted in the case by two screws from the rear of the chassis. A special front panel is provided to simplify operation.

G. Testing

The tests conducted on the prototype ear microphones are outlined below. Tests were conducted on the actual components configured in breadboard for prior to assembly, welding and potting to insure proper operation of the prototypes.

1. Microphone Tests

The microphones were tested for sensitivity as a microphone and earphone. The units were also tested in accordance with the matching procedure as outlined in the diplexer design section. The microphones used in the first prototype exhibited a minimum isolation of 37 db and the second pair a minimum of 35 db. The sensitivity of each as a microphone at lkc was -77 for both microphones. The receiver sensitivity was +105 db with 300 mv and 600 ohms at lkc.

2. Diplexer Tests

Diplexer gain and isolation were measured on the prototype units as follows:

	Unit 1	Unit 2
Gain	40	38
Isolation	37 db (min)	35 db (min)

The diplexer was also tested qualitatively with a hard wire communications link. The isolation of each was adequate but when the gain was increased over a moderate listening level, the voice feedback increased above the direct signal. This effect can be significantly reduced by limiting the bandwidth below 3000 cps.

3. Transceiver Tests

The transceivers were tested for several timing and performance parameters. These parameters are listed below:

Parameter	No. 1	No. 2	Units
Tuning Range	180-230	185-240	mc
TX Pulse Width	15	16	Usec
RX Pulse Width	2.7	2.9	Usec
Recurrence Time	34	35	Usec
RX Sensitivity	27	30	Uvolts
TX Power	≈1.5	≈2.0	mw
Video Output	1.8	1.8	volts
AGC Dynamic Range	70	70	db
RX Bandwidth	820	930	kc

A few parameters were measured in a qualitative way such as transmitter detuning effect when body mounted and detuning with antenna length.

These effects interact and represent less than 2 mc under all conditions. The receiver bandwidth varies with signal level which is typical of super regenerative receivers.

4. Master Station Tests

The master station was tested for overall performance parameters and the results are summarized below:

Parameter	Result
Receiver Sensitivity	8 μvolt (20 db quieting)
Receiver Bandwidth	1 mc
AFC Range	1 mc
SYNC Recurrence (idle)	36 μ sec
SYNC Pulse Width	3.1 μ sec
Transmitter Delay	19.8 μ sec
Modulator Pulse Width	9.6 μsec
Blanking Pulse Width	9.8 μ sec
Transmitter Power	2.8 watts (peak)
Total 20 Volt Current	67 ma

5. RF Link Tests

The ear mike transceiver and master station were tested as a system to evaluate the RF link performance. The master station was calibrated to 195 mc to avoid interference from T.V. stations. The ear mike was calibrated to the master station for optimum reception. The tests were conducted with the master station in a tower approximately 15 feet off the ground. The ear mike was mounted on a subject and tested for range.

The results indicated a reliable communication range in excess of 100 yards.

A problem was encountered while operating within a building of near obstructions such as fences, buildings, etc. This problem was due to multipath transmission causing addition and cancellation of the signal. During these tests several adjustments were made in the master station to improve operation. The timing and transmitter to receiver leakage were improved to establish reliable communication.

6. Hard Wire Tests

Hard wire tests were conducted with the ear mikes in a noise environment without ear defenders. The intelligibility was measured with 100 db of noise at 50% on three subjects. The tests were conducted using a standard microphone and head set to complete the loop.

SECTION V

OPERATION AND ALIGNMENT

The operation of the ear mike transceiver should be conducted in an area to avoid multipath transmission if possible.

A. Ear Mike Installation (Figure 25.)

The ear mike is installed by placing the insert section in the right ear and firmly seating the tip in the ear canal. The transceiver is then plugged into the diplexer section to assure good contact. The unit is then adjusted for comfort on the ear and the seal of the insert checked. The battery pack is worn in a shirt or coat pocket and the lead is coupled close to the body up to the ear mike. The antenna should extend from 8 to 10 inches. The ear mike is turned on when the power connector is plugged in. The battery pack should operate the ear mike up to 240 hours.

B. Master Station Operation

The antennas are extended approximately 18 to 20 inches. The on-off switch turns the entire system on. Prior to synchronization, the ear microphone will receive a squeal representing the difference between the master station and ear mike P.R.F. When synchronization occurs, the ear mike will be quiet until communication is established. When the master station is turned off, the ear mike will receive only noise.

The A. F. C. switch provides either A. F. C. or manual operation. The tuning should be accomplished with the A. F. C. switch in the off position. When the ear mike is received, the A. F. C. is switched to on. The bandwidth switch selects the master station audio bandwidth. The FM, AM, standby switch should be in AM position. Standby position removes the B^+ from the receiver portion.

The tuning adjustment is used to locate the ear mike signal in the band. Synchronization is automatic once the ear mike received. The master station volume controls the speaker/phone audio gain. The ear mike volume controls the modulation of the transmitter and hence the volume of the ear mike. The master station microphone is a push to talk type and the ear phones disable the speaker when plugged in.

C. Alignment

The alignment of the system requires that the ear mike battery pack is providing -4.1 and +1.4 volts at the battery terminals. The alignment also assumes the receiver portion of the system is operating properly.

1. Master Station Transmitter Tuning

The unit must be removed from the case to tune the transmitter. The unit is held with two screws from the rear and slide out forward. The antenna cables are disconnected when removing. The equipment required to align the transmitter includes:

1 step attenuator - kay - 40 db

1 wattmeter - Bird - 0-25 mw

1 tektronix model 547 Scope and plug in

1 Grid Dip Meter (or receiver)

1 Alignment Cover

1 High Frequency Alignment Tool

The attenuator and wattmeter are connected to the transmitter output with 50 ohm cable. The alignment cover is installed to line up with the tuning adjustments. The scope is connected to the 100 pfd feed-through capacitor (orange lead) on top of the transmitter between the component boards. The attenuator is set to 10 db and the master station is turned on. The capacitor C-23 controls the frequency and C-27 and C-28 control the power amplifier matching. The matching adjustments do interact with the tuning.

The wave form on the scope is the modulator pulse. Misalignment of the receiver causing mismatch will be indicated by an abrupt change in the wave form and power output. The frequency is tuned by removing the wattmeter and connecting an antenna. The frequency is noted on a grid dip meter or a standard receiver. The matching controls are adjusted with the wattmeter connected for maximum neutralized power. An abrupt increase in power indicates the power amplifier matching network is adjusted to un-neutralize the circuit. When properly adjusted, the wattmeter will indicate approximately 100 mw of power.

2. <u>Ear Mike Transceiver Alignment</u>

The ear mike transceiver has two controls. The +1.4 volt bias adjustment on the battery pack and the frequency adjustment. The bias is adjusted, with the master station off, to achieve a noise pulse at the test point on the ear mike. The noise is adjusted for approximately 1.2 volts peak.

This adjustment interacts with frequency, hence it should be checked afte: change ear mike frequency.

The frequency adjustment is made when the ear mike is installed on a subject's ear to account for detuning effects from the body. The ear mike frequency is adjusted to the master station transmitter for best reception. This adjustment requires that the master station receiver is constantly retuned to assure proper synchronization.

3. Battery Replacement

The batteries should be replaced when the open circuit voltages drop below -1.4 and +1.35 volts. Four Phillips head screws retain the battery pack cover. The replacement cells are Burgess type Hg-9 or equivalent.

SECTION VI

CONCLUSIONS

The concept of the wireless ear microphone communication system has been successfully demonstrated. Speech signals sensed in the ear can provide intelligible communication. Intelligibility in a high noise environment is improved over conventional techniques. The optimum intelligibility in a high noise environment can be improved with further ear transducer development and noise concelling techniques.

The diplexing technique provides a minimum isolation of 35 db which is adequate for simultaneous communication. The dual transducer diplexing technique also suggests the potential for noise cancelling. Preliminary experiments indicate an improvement of 10 db can be achieved.

A universal ear insert was developed permitting interchangeability and good performance in a high noise environment. The device was tested for comfort and can be worn up to 8 hours with no irritations or discomfort to the subject.

The ear mike transceiver was packaged in an ear mounted configuration to demonstrate system operation direct from the ear. The problem areas associated with RF transmission and body loading near the ear were solved for this application. Special RF shields were incorporated in the design. The RF section was fabricated with an ultra-miniature technique providing a transmitter and receiver in the volume of a sugar cube.

The work conducted on this program has resulted in several state of the art advances in short range communication. The time multiplex RF link provides simultaneous hands of communication without frequency duplex techniques and has potential to provide several channels in a narrow frequency band.

The program also has suggested that further development of ear transducers and diplexing techniques can yield communication in extremely high acoustic noise environments.